Hydrologic Processes Modeling

Workshop

Tucson, Arizona
November 8-9, 2000

ACKNOWLEDGEMENTS

This Workshop on Hydrologic Process Modeling and the report you are reading would not have been possible without the efforts of many individuals. These people gave of themselves because they care about hydrologic modeling, their profession, and because they want to see technology used for better resource decision making. The concept to pursue this workshop would not have been possible without the support from the Subcommittee on Hydrology (SOH). The SOH in their foresight established the Task Committee on Hydrologic Modeling and allowed those members the freedom to organize and convene this workshop. Appreciation is extended to all members on the Task Committee on Hydrologic Modeling, which includes:

Mimi Dannel; Russ Kinnerson, Arlen Feldman; Marshall Flug; Donald Frevert, Chair; Doug Glysson; George Leavesley; Steve Markstrom; Jayantha Obeysekera; Mike Smith; Ming Tseng; Don Woodward; and Ray Whittemore.

In addition, the University of Arizona provided our host facility, arranged the logistical details for the workshop, and provided a great environment for this workshop. Special appreciation is extended to Paul Baltes for making the on site arrangements for the workshop and to Pam Lawler, for assisting Paul with the on-site arrangements and also handling the registration for this workshop. Soroosh Sorooshian, who initially agreed to get the UA involved as host facility, and Hoshin Gupta, both of SAHRA as well as Jim Washburne, Assistant Director for Education at the UA are owed our thanks for arranging and coordinating UA's faculty, staff and student support of this workshop.

Special thanks are extended to Terri Sue Hogue for scheduling and overseeing the students from the University of Arizona that served as note takers, recorders, and prepared the written Discussions for the four Panels and of the Breakout sessions. Of course we greatly thank and appreciate the students that gave their time and extra hours to make sense of the notes they took during the workshop. These students are:

Tom Pagno; Felipe Ip; Dave Gochis; Eleanor Burke; Fezan Misirli; Kristie Franz; Holy Hartmann; Terri Sue Hogue; Newsha Khodatalab; and Hamid Moroadkhani.

We would also like to extend our sincere thanks to the invited speakers, panelists, and participants that helped make this workshop a huge success.

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Hydrologic Processes Modeling Workshop

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Objectives

- Identify current models with Surface Water purposes or components
- Review previous models comparisons projects/publications
- Develop checklist/criteria for user assessment of models to meet needs
- Identify data sets for testing/comparing models
- Investigate potential for unifying software design and resource libraries
- Develop information to help plan conference in 2002

Acknowledgements

November 8th - Wednesday

7:30-8:30 **Registration**

8:30-9:30 **Plenary session**

a. **Welcome and logistics – Don Frevert, BOR and Soroosh Sorooshian, U. Arizona**
b. **History of Subcommittee on Hydrology and other committees in ACWI - Tom Yorke, USGS**
c. **Review of Las Vegas April 1998 Conference - Don Woodward, NRCS**
d. **Objectives of this Workshop - Arlen Feldman, Corps**

9:30-10:00 Break

10:00-12:00 **Panel 1**: Software Development Philosophy and Environment

Issues: Modular design, integration with larger systems, graphic user interface, graphics, multi-platform verus single system, object-oriented programming, design for primary customers - or profession, proprietary or public domain, GIS basis or pre/post processing, etc.

Moderator: Edith Zagona, CADSWES

a. **Modular Modeling System – George Leavesley, USGS**
b. **HEC Next-Generation Software – Darryl Davis, Corps**
c. **Mike SHE – Henrik Sorensen, Danish Hydraulics Institute**
d. **Models 2000 – Robert Carousel, EPA**
e. **Spatial Hydrologic Modeling – David Maidment, U. Texas**

12:00- 1:30 Lunch

1:30-3:00 **Panel 2**: Roles of State/Federal/University/Private Organizations

Issues: Public-domain or proprietary status for software developed with public money, value added by distributors, copyright public-domain code, licensing, long-term maintenance, user fees, etc.

Moderator: David Ford, Ford Consulting Engineers

a. **University – Jim Nelson, BYU**
b. **Federal – Mike Smith, NWS**
c. **Private software developer – Tony Donigian, Aqua Terra**
d. **Private software distributor – Sasa Tomic, Haestad Methods**
e. **State – Sushil Arora, California**

3:00-3:30 Break

3:30-5:00 **Panel 3**: Appropriate use and Guidance for use of models

Issues: User expertise required, control of user qualifications, easy-to-use misuse of models, guidance for appropriate use, independence from model developer, etc.

Moderator: Don Woodward, NRCS

a. **South Florida Water Mgmt Dist. – Obey Obeysekera**
b. **Natural Resources Conservation Service – Bill Merkel**
c. **Hydrocomp, Inc. – Norm Crawford**
d. **Oregon State University – Wayne Huber**
e. **Lower Colorado River Authority, TX – Quentin Martin**

6:00-8:00 Icebreaker/Dinner

November 9th - Thursday

8:00-9:30 **Panel 4**: Measures of Models' Performance

Issues: Comparisons in the literature, standard data sets and test results, ISO 9000 certification, statistical and graphical tools to assess data and results, etc.

Moderator: Ming Tseng, Corps

a. **Univ. of Georgia – George Vellidis**
b. **Agricultural Research Service – David Goodrich**
c. **Hydrosphere, Inc. – Ben Harding**
d. **Illinois Water Survey - Misganaw Dimissie (no written summary)**
e. **Univ. of Arizona – Soroosh Sorooshian**

9:30-10:00 Break

10:00-12:00 **Breakout sessions** (same moderators as for Panels)

Objectives: The breakout sessions will summarize the comments provided throughout the workshop with respect to their panel subject. Additional needs and problems will be identified. These results will be presented to the workshop in the following 'reporting' session as well as be used for the workshop report. Special attention should be given to making recommendations for how to best address these needs/problems in the 2002 conference. The conference planners will use this information to better address these subjects.

Panel 1: Software Development Philosophy and Environment

Panel 2: Roles of State/Federal/University/Private Organizations

Panel 3: Appropriate use and Guidance for use of models

Panel 4: Measures of Models' Performance

12:00-1:30 Lunch

1:30-3:00 **Reports of breakout groups**

3:00-3:30 Break

3:30-5:00 **Closing**: Summarize workshop
Make recommendations/assignments for 2002 Conference
Discuss/make assignments for Workshop Report

Additional Attachments

Original List of Questions Posed to the Four Panels

This list was compiled from input provided by each invited workshop attendee. All participants were asked to provide input, prior to the workshop, in the form of topics for each of the four panels to discuss or questions that need to be addressed.

List of Workshop Attendees

Plenary Session - Item A
Welcome and logistics
Don Frevert, US BOR and Soroosh Sorooshian, Univ. of Arizona

The Task Committee on Hydrologic Modeling, of the Subcommittee on Hydrology, asked Soroosh Sorooshian if the University of Arizona would be willing to assist with and host this Hydrologic Processes Modeling Workshop. The University of Arizona has a long history and is a leading institution in the area of Hydrology and Watershed Management. Soroosh Sorooshian now serves as Director for a new National Science Foundation established Science and Technology Center for Sustainability of semi-Arid Hydrology and Riparian Areas (SAHRA), located at the University of Arizona. The Mission of SAHRA is:

> to promote sustainable management of water resources in semi-arid regions through stakeholder-driven interdisciplinary research, aggressive public outreach and strong education initiatives, leading to rapid dissemination and application of cutting-edge scientific knowledge.

Complete information on SAHRA is available on the following web site:
www.sahra.arizona.edu

Plenary Session - Item B
History of Subcommittee on Hydrology and other committees in ACWI
Tom Yorke, USGS

The **S**ubcommittee **o**n **H**ydrology (**SOH**) started out as a Federal interagency group operating within the federal government for over fifty years now. A brief history of the committee and the organization it reported is provided in the to following list.

* October 1, 1945 - First meeting held, organized under the Federal Inter-Agency River Basin Committee
* September 14, 1954 - Inter-Agency Committee on Water Resources
* June 7, 1966 - Water Resources Council
* Dec. 7, 1982 - Inter-Agency Advisory Committee on Water Data
* Dec. 10, 1991 - **W**ater **I**nformation **C**oordination **P**rogram (**WICP**)
* Aug. 8, 1998 - **A**dvisory **C**ommittee on **W**ater **I**nformation (**ACWI**)

The SOH now reports directly to the ACWI, which operates under the Federal Advisory Committee Act (FACA). The lead agency for overseeing WICP is the US Geological Survey (USGS). Under this structure the membership in the SOH includes Federal, interstate, State, Tribal, and local government agencies, as well as private and non-profit organizations. Complete and updated information on ACWI, WICP, as well as the Terms of Reference for the SOH is available at the following web site:
http://water.usgs.gov/wicp/acwi/hydrology/hydrotref.html

As the parent organization the SOH changed over the years, as did the Purpose; membership and participation in the SOH; as well as the activities (including subcommittees and Task groups) of the SOH. A brief statement of Purpose from 1945 and 1988 are given here.

Original 1945 Purpose: To develop and recommend continuing procedures to coordinate activities in the collection, analysis, and interpretation of hydrologic data.

Modified 1998 Purpose: To identify water information needs, evaluate the effectiveness of water information programs and recommend improvements.

The membership in the SOH has greatly expanded over time as follows.

1945 Membership:

Dept. of Agriculture – Soil Conservation Service
Dept. of the Army – Corps of Engineers
Dept. of Commerce – Weather Bureau
Dept. of the Interior – Geological Survey
Federal Power Commission
Tennessee Valley Authority

1963 Expanded Membership:

Dept. of the Army – Corps of Engineers
Dept. of Health, Education and Welfare – Public Health Service
Dept. of Commerce – Bureau of Public Roads; Weather Bureau
Dept. of Agriculture – Agricultural Research Service; Forest Service; Soil Conservation Service
Dept. of the Interior – Bureau of Mines; Bureau of Reclamation; National Park Service; Bureau of Land Management; Bureau of Indian Affairs; Bureau of Sport Fisheries and Wildlife; Geological Survey
Federal Power Commission
Tennessee Valley Authority

2000 Subcommittee on Hydrology Membership:
Agricultural Research Service
American Society of Civil Engineers
Association of State Floodplain Managers
Bureau of Land Management
Bureau of Reclamation
Defenders of Property Rights
Federal Energy Regulatory Commission
Federal Emergency Management Agency
Federal Highway Administration
National Hydrologic Warning Council
National Science Foundation
National Weather Service
Natural Resources Conservation Service
U.S. Army Corps of Engineers
U.S. Environmental Protection Agency
U.S. Forest Service
U.S. Geological Survey

Along with the changes in SOH membership and purpose is the changing tasks best identified by the existence of the following SOH Work Groups.

1951 - Water Quality;Snow; Bibliography; Waves; Hydrologic Networks; and Drainage area size.
1960's - Ground Water; Flow Frequency Analysis; Water Quality; Bibliography; Radio Frequency; Alaska Networks.
2000 - Hydrologic Modeling; Flow Frequency Analysis; Streamgaging Network.

The significant documents associated with these Work groups include the following representative SOH Products:
* Instructions for compilation of Unit Hydrograph Data
* Requirements for additional hydrologic stations to meet Federal needs
* Uniform technique for determining flood flow frequencies
* Hydrologic Unit Maps
* 1998 - First Inter-Agency Hydrologic Modeling Conference

A brief overview of current Advisory Committee on Water Information (ACWI) Activities is given in the following list.

National Water Quality Monitoring Council
NAWQA National Liaison Committee
Subcommittee on Spatial Water Data
Subcommittee on Hydrology (SOH)
Task Forces
Federal-State Cooperative Water Program (COOP) Task Force
Streamgaging Task Force

A current listing of SOH activities and meeting minutes are maintained at the previously cited web site given above. In addition this web site can be used to locate information on ACWI and WICP. http://water.usgs.gov/wicp/acwi/hydrology/hydrotref.html

Plenary Session - Item C
Review of Las Vegas April 1998 Conference
Don Woodward, NRCS

I was asked to review the previous Workshop held in Las Vegas, Nevada, in April of 1998. Before describing this federal interagency work, I would like to review two earlier sessions that indicate the development of these hydrologic workshops.

The first workshop was held in Pingree Park, Colorado in 1983. It was a joint ARS/SCS workshop. The purpose was to discuss the SCS hydrologic model needs and to present the state of the art concepts and models. The outcome was better communications between agencies and a recommendation for another workshop in the future.

The next workshop was the Federal Interagency Workshop on the Hydrologic Modeling Demands for the 90's held in Fort Collins, Colorado, in 1993. The purpose of this federal agency workshop was to facilitate information sharing and technology transfer, to coordinate funding, staffing and other capabilities that insure best use of available resources. The workshop primarily dealt with water quantity issues. The outcome was a better understanding of each other's activities in the modeling arena. The workshop agenda did include a poster and a computer model demonstration session. Participation in the workshop was by invitation. One of the recommendations was to hold another workshop.

The First Federal Interagency Hydrology Modeling Conference was held in Las Vegas, Nevada, in 1998. The Interagency Advisory Committee on Water Data (IACWD) sponsored this workshop. However, there was an effort by the federal agencies planning committee to open the workshop to private sector and to send invitations to foreign countries. There were presentations from foreign countries and private countries. The key point speaker was from the academic sector. There were panel members from the private sector to discuss their role and contributions to the modeling effort. There were oral presentations and computer presentations. The primary purpose of the conference was to promote technology exchange among governmental agencies academic institutions and private sectors in hydrologic modeling. The workshop was very successful with over 400 participants, 133 papers or presentations, and 21 demonstrations. The planning committee decided that both water quality and quantity issues should be discussed.

Major topics for the conferences included new modeling systems, hydrology, extreme events, river hydraulics and flow/stage forecasting, river and reservoir system, erosion and environmental/watershed. One of the recommendations was to hold another workshop in three to five years.

The Subcommittee on Hydrology (SOH) established a task force to address this recommendation. The SOH is under the umbrella of the Advisory Committee on Water Information (ACWI). ACWI is an open organization with representation from all sectors dealing with hydrology. The planning committee had members from all sectors.

This workshop is the first step in the planning process to hold another conference in 2002.
I am very pleased to see the growth of sponsoring groups within my time frame.

Plenary Session - Item D
Objectives of this Workshop
Arlen D. Feldman, HEC, USACE

The idea for this workshop came about as a result of the Las Vegas Conference in 1998. That conference clearly had many kindred hydrologic modeling spirits; similar models were presented and applications made. It was a good opportunity to display one's latest accomplishments to modeling colleagues.

Coincident with this feeling of modeling well being was the impression by some that there was considerable duplication of effort. Duplication of effort in itself is not necessarily bad; in fact, redundancy is a stated systems principle for both security and competition. The main concern was how to best share ideas and resources for the greater good.

Each agency has its responsibilities, particular approaches, and needs for hydrologic information. The underlying hydrology is the same but its conceptualization differs with the applications needs. The modelers generally learn from one another at meetings such as this and through agency reports, technical society meetings and journals, and texts. Common areas of modeling-capability development were: data collection and analysis, efficient data storage for use by models, modular formulation of computer codes, GIS support to model's data formulation, graphic user interfaces for old and new computer codes, and powerful graphics for visualizing data and results.

Less apparent in the presentations were common methods of software development and means/plans for model maintenance and user support. Developers both revel in a large user base and suffer from the resources taken for user support. Likewise, there was little systematic attention paid to model documentation and guidance for proper use. There is a general sense of: if you build it (well), they (users) will come.

Hence the need for this workshop arose to address model development, documentation, and support concerns as opposed to the usual meeting format to present model capabilities. The original objectives of the workshop were:

Identify current models with Surface Water purposes or components
Develop summary fact sheets on each model's purposes and capabilities
Review previous models comparisons projects/publications
Develop checklist/criteria for user assessment of models to meet needs
Identify data sets for testing/comparing models
Investigate potential for unifying software design and resource libraries
Plan conference in 2002

The workshop was organized into a plenary session and four panels of national experts to address the above concerns. The four panel subjects were:

Software Development Philosophies and Environment
Roles of State/Federal/University/Private Organizations
Appropriate use and Guidance for use of models
Measures of Models' Performance

Panelists briefly summarized their views and activities with respect to the issues identified for each panel. Discussions after the presentation debated/elaborated on the ideas presented. After the completion of the fourth panel session, each panel, together with interested participants, met separately to summarize thoughts on their topic that has arisen throughout all panel discussions. The panel moderator then summarized the thoughts on their topic in a summary session.

The panelists provided brief summaries of their comments, which are included in these proceedings. University of Arizona graduate students took notes on the discussions following each panel, which are also included. Summary statements and discussion notes from each panel breakout session conclude these proceedings. One objective of this workshop was to investigate subjects for the next full conference in 2002. These proceedings provide a wealth of subjects and concerns to be addressed at that conference.

Panel 1: Software Development Philosophy and Environment - Item A
Modular Modeling System (MMS) - A Modular Approach to Model Software Development
George H. Leavesley, USGS

The interdisciplinary nature and increasing complexity of environmental and water-resource problems require the use of distributed modeling approaches that can incorporate knowledge from a broad range of scientific disciplines. Selection of a model to address these problems is difficult given the large number of available models and the limited information available with which to objectively compare models. A modular approach provides a framework in which to focus the multidisciplinary research and operational efforts needed to facilitate the selection and application of the most robust distributed modeling methods to address these complex problems.

This argument is based on the premises that:

1. There are no universal models.
2. Models for different purposes require different levels of detail and comprehensiveness.
3. Appropriate model process conceptualizations are a function of problem objectives, data constraints, and spatial and temporal scales of application.

It follows from these premises that for a given set of problem objectives, data constraints, and spatial and temporal scales of application, an optimal model can be created by coupling the appropriate process conceptualizations for a given set of criteria. This concept also requires that we change the question of "which model is most appropriate for a specific set of criteria?" to "what combination of process conceptualizations is most appropriate?"

While simple in concept, the selection of appropriate process conceptualizations is not a trivial task, given the current state of process understanding and distributed modeling technology. Much research remains to be done to define the appropriate process conceptualizations and the most robust distributed-modeling techniques for the various combinations of criteria. Knowledge gained from these efforts, however, will serve to move the art and science of distributed hydrological modeling forward.

To facilitate the application of modular concepts to distributed hydrological models, the U.S. Geological Survey (USGS) Modular Modeling System (MMS) has been developed. MMS is an integrated system of computer software developed to (1) provide the research and operational framework needed to enhance development, testing, and evaluation of physical-process algorithms; (2) facilitate integration of user-selected algorithms into operational physical-process models; (3) facilitate the coupling of models for application to complex, multidisciplinary problems; and (4) provide a wide range of analysis and support tools for research and operational applications. MMS expands the use of modularity from simple model structure to include the integration of models and tools at a variety of levels of modular design. The result is a modular "tool box" of modules, models, and support tools for the research, development, testing, and operational application of distributed hydrological models.
Levels of Modular Design

Modular design concepts can be applied at several levels of model development and support in MMS. These include individual process models, tightly coupled models, loosely coupled models, fully-integrated decision support systems, and a variety of analysis and support tools.

At the process and individual model level, MMS uses a master library that contains compatible modules for simulating a variety of water, energy, and biogeochemical processes. The library may contain several modules for a given process, each representing an alternative conceptualization or approach to simulating that process. An "optimal" model is created by selectively coupling appropriate modules from the library to create a suitable model for the desired application.

The paradigm of linking modules to create a model can also be applied to the linking of models to create a larger integrated model. In this case the individual models can be considered as mega-modules. Fully coupled models refer to the coupling of individual models where there is a two-way flow of information between the models. These typically are developed to provide feedback among related processes in the linked models.

The module linking paradigm for model building applies to loosely coupled models as well. In loosely coupled models, however, information flow is in only one direction; output from one model is used as input to another model. The link between models is accomplished using a common database.

Decision support systems (DSS) are the top level of complexity for model coupling and integration. Various combinations of models from all levels of modular design can be integrated with resource management and decision support models to create a resource management DSS. The ability to couple and integrate models for DSS development and application are provided in MMS by the Object User Interface (OUI) tool set.

Analysis and support tools are also included as modular components of the system design. The GIS Weasel is a geographic information system (GIS) interface for the application of a variety of GIS tools to delineate, characterize, and parameterize topographical, hydrological, and biological basin features for use in a variety of lumped- and distributed-modeling approaches. The Object User Interface (OUI) is a map-based interface for acquiring, organizing, browsing, and analyzing spatial and temporal data, and for executing individual and coupled models and analysis tools. Optimization and sensitivity analysis tools are provided to analyze model parameters and evaluate the extent to which uncertainty in model parameters affects uncertainty in simulation results. Forecast methods provided include the use of historical data as an analog for the future and statistical downscaling procedures using output from atmospheric models.

Summary and Conclusions

To obtain maximum benefit from the modular concept, participation by the hydrologic modeling community is needed. This participation comes with the costs of a willingness to share in the design and acceptance of a modular coding structure, the willingness to develop and share module code, and the willingness to share data for the development of distributed data sets in a wide range of climatic and physiographic regions of the world. Loss of model name recognition is also a possible cost when process modules from a number of different models are combined to create a new model. The new model name may not reflect any of the original models from which the modules where obtained.

The benefits of participation, however, include the ability of modelers to share resources and be part of a larger multidisciplinary research effort where individual modules can be developed by those with the relevant process expertise and be provided in a common toolbox with a wide range of analytical and support tools. Implementation of a common modular concept is not a trivial task. However, it would bring the resources of a larger community to bear on the problems of distributed modeling, provide a framework in which to objectively compare alternative modeling approaches, and provide a means of sharing the latest modeling advances.

MMS is an integrated system of computer software that has been developed to provide a common modular framework in which to address the issues of model design, scale, and parameter estimation in distributed hydrological modeling. Continued advances in physical and biological sciences, GIS technology, computer technology, and data resources will expand the need for a dynamic set of tools to incorporate these advances in a wide range of interdisciplinary research and operational applications. MMS is being developed as a flexible framework in which to integrate these activities with improved knowledge of hydrological and meteorological processes to advance the art and science of distributed hydrological modeling.

Further information on MMS can be found at:

http://wwwbrr.cr.usgs.gov/mms/
http://wwwbrr.cr.usgs.gov/weasel
http://wwwbrr.cr.usgs.gov/warsmp

Panel 1: Software Development Philosophy and Environment - Item B
Hydrologic Engineering Center Views
Darryl W. Davis, Director HEC

On Design: HEC software is designed to provide the computation needs of Corps field offices in their execution of the Corps Civil Works Water Resources program. Hydrologic engineering analysis is needed for planning investigations for the full suite of water management settings and purposes; for design studies for river management and a variety of hydraulic structures; for water management plan development and real-time project monitoring and operation; and for regulatory and permitting actions. We make special efforts to engage the profession in scoping and testing software by inviting input from professionals around the world. We believe that this approach serves the Corps and the profession well. Generally, software has evolved to incorporate ever-increasing ability to use new data sources, better represent hydrologic and hydraulic processes, and adapt to improved computation and user environments. With the HEC NexGen project, a step back, re-look at the fundamental algorithms and code structure of existing software resulted in replacing a number of popular and widely used programs with new software. That project is well along with most new successor software packages released and improved several times since initial release.

On Integration: Integration here is taken to be the ability to make use of a number of hydrologic and other models for analysis without requiring undue intervention by the user, in-effect enabling seamless executions of analysis scenarios. This is, of course, the practical need for most studies today. Very seldom is the situation under study only a runoff problem, or river hydraulics problem, or reservoir operation problem, or even just a hydrologic problem alone. The NexGen project has addressed this on two fronts: by using the HEC-DSS time series and paired data system for managing model data in all stand alone HEC software; and by developing an integrated system of data acquisition, data management, and real-time forecast and decision support modeling coined the 'Corps Water Management System', CWMS. The CWMS system will be deployed Corps-wide beginning in late FY 2001. A watershed version (comprehensive study incarnation) of the CWMS system is under development that will be released shortly following the CWMS system deployment. The HEC-DSS system has data import and export capabilities that enable integration with other parties' software, and the CWMS uses a well structured ORACLE database, also enabling import/export of data for model sharing and integration. CWMS is script enabled to permit custom automating and scheduling of functions and executions. The HEC models in CWMS are thus script enabled, but limited. Scripting in HEC software will be expanded in future version.

On GUIs and Multi-platform: While most HEC software use occurs on Windows desktop workstations, we believe we must deliver to Corps users, platform portable software packages. With the exception of the stand-alone HEC-RAS program, the current generation of software (NexGen project) is multi-platform. The software features that for the most part relate to multi-platform are the Graphical User Interface (GUI) and graphics. The HEC-RAS compute engine is in Fortran, thus platform portable, but the GUI and graphics are written in Visual Basic, thus RAS is Windows dependent. We wish this were not the case, but time and circumstances (pressing milestones and code language availability at the time) led to this outcome. Two other major software packages (HEC-HMS - runoff model, and HEC-FDA - flood damage model) made use of a multi-platform development environment named Galaxy. Unfortunately (or fortunately depending on one's perspective), the emergence of the JAVA language killed the commercial viability of Galaxy, and the GUIs for these programs are being redone. At the same time, we are replacing the graphics with a new graphics library written in JAVA that will ensure that these programs are multi-platform. The newest of the NexGen programs, HEC-ResSim - reservoir simulation analysis, has been designed to be fully object-oriented, and coded in JAVA. ResSim, like other HEC software, makes use of a few legacy Fortran library routines. The CWMS system mentioned above is client-server architecture software wherein the server (which hosts the data base and executes the forecast and decision support models) is SUN Solaris, and the client platform (for the Control and Visualization Interface) is Windows NT/2000. Thus the platform portability of the HEC software is a paramount importance. We developed a JAVA-based special GUI for HEC-RAS for CWMS.

On Object-Oriented Design and Programming: We have strived to develop the new generation of HEC software as object-oriented concepts with greater success for some software packages than others. We remained skeptical for several years as to the reality of the promised payoff, continuing to notice that the "Emperor had few, if any clothes" on this issue for considerable time. Developing staff capability to be efficiently productive in this new and different design and coding world required significant cultural change among the engineering and software support staff. It has not been an easy transition and is not yet complete. None-the-less, we are now convinced that object-oriented design and coding are paying off handsomely, with much reusable code among the new software. JAVA is HEC's object-oriented coding language of choice. That said, most of the NexGen programs have residual legacy code (Fortran, some C and some C++) making it necessary to be flexible in assembling the code into a compiled executable. We do make use of a JAVA code development environment to ease code development for the GUI and graphics components.

On Proprietary Vs Public Domain: As noted above, HEC software is designed to provide the computation needs of Corps field offices in their execution of the Corps Civil Works Water Resources program. HEC software is developed at Federal expense. Our approach at HEC to serving the public interest with taxpayer funds is to make the software available to the public for their use. We have developed the software for Corps use, but the public is welcome to have and use it as they see fit. The issue of proprietary Vs public domain is a legal question involving intellectual property ownership. In short, if software is developed with public (Federal) resources, it is public property and is considered to be public domain; a Federal agency may not declare otherwise. The term 'resources' is the key, and here it means with Federal staff resources, not funds. Software developed under contract with Federal funds can be viewed as the intellectual property of the developer and may be protected by copyright. The only legal protection that appears to be available for software developed with Federal staff resources is that of a Trade Name, e.g. HEC could Trade Name protect its software. While most HEC software has some commercial components, and contractor developed code (some programs more, some less), we consider HEC software to be public domain and we behave accordingly. We make the executable code publicly available when released to Corps offices, and make the source code available when we judge the software to be mature, meaning no longer in the intense development phase. On a case-by-case basis, we have shared new software code with other Federal agencies.

On GIS Vs Model Centric Software Design: We view HEC software as engineering tools and not GIS applications - hence we are in the 'model-centric' as contrasted to the 'GIS centric' camp. GIS information is important, and in some instances, critical, to high quality hydrologic engineering and planning analysis model applications. We provide a map background display for most of the HEC software user interfaces to provide geographic context, but the backgrounds are generally passive images. Most of the software is now geospatial enabled, so that real-world coordinates may be used. While not required in general, geospatial referencing is necessary for a number of capabilities, such as flood plain inundation mapping, flood plain structure inventory, etc. Our approach is to develop GIS-based utility software (we refer to as geo-utilities) that uses readily available commercial GIS software and public and private data sources. GIS software 'Extensions' are written that extract, analyze, and tailor the GIS data to the information and format needs of HEC software. We have a Cooperative Research and Development Agreement (CRADA) with Environmental Systems Research Institute (ESRI) that has yielded geo-utilities for HEC software. These are: HEC-GeoRAS - cross section extraction, inundation mapping, and hydraulic parameter derivation; and HEC-GeoHMS - watershed delineation and parameter development, and grid runoff model data development. Another geo-utility, being developed in-house, is HEC-GeoFDA - flood damage function development and analysis.

Panel 1: Software Development Philosophy and Environment - Item C
Danish Hydraulic Institute (DHI) Software, Mike SHE
Henrik R. Sorensen, Senior Hydrologist DHI Water & Environment

Introduction to DHI
DHI Water & Environment is a private, not for -profit research and consultancy organization. DHI works worldwide and staffs around 500 of which about 300 holds M.Sc. or Ph.D degrees. DHI's objective is to build competence and promote technological development to the water and the environment. DHI Inc (subsidiary of DHI) is located in Philadelphia, PA and conducts projects in North America and provides technical support to users of DHI software (see www.dhi.dk and http://www.dhigroup.com/). A major part of DHI's activities are related to software development and research; and about 100-125 staff members work full-time with research or software development.

DHI Software Today
DHI software (see http://www.dhisoftware.com/) today covers all aspects of water, water quality and sediment transport ranging from urban hydrology, water distribution systems, watershed management, flood management and coastal and harbor engineering and off-shore technology. During recent years DHI has worked on integrating several of the DHI software packages. For instance DHI already offers models that combine 1-dimensional and 2-dimensional approaches in one model. For instance a flood-model can be designed with a 1-dimensional hydrodynamic river model (MIKE11) that covers the main channel and a 2-dimensional model covering the floodplains (MIKE21). Another good example on model integration is the physically based integrated modeling system MIKE SHE that fully integrates surface water and groundwater flow regimes, both with respect to water and water quality. In the integrated MIKE SHE modeling system MIKE11 constitutes the hydraulic (river) model. MIKE SHE has been adopted for several integrated modeling studies by South Florida Water Management District.

DHI Software Tomorrow
Integration of models and modular design are key words for future DHI software systems. DHI will over the coming years invests large resources in development of integrated modeling approaches and in new integrated solvers.

The vision is that DHI software users should have full flexibility with regard to selection of modeling approach. This may include both integration of different models and 1D, 2D or 3D solvers. For instance MIKE SHE and MOUSE (sewer model) may be integrated to study sewer interactions with groundwater and MIKE11 and MIKE21 may be coupled to build an integrated river (MIKE11) and estuary model (MIKE21 or MIKE3 2D/3D). Further DHI software will be based on a more open COM based architecture that will facilitate development of interfaces with other proprietary codes or public-domain codes easier.

DHI software is GIS interfaced (ArcView/ArcInfo) and DHI is involved in the ESRI water resources consortium (headed by David Maidment). The water resources consortium is tasked with definition and development of a water resources geo-object database model within the ARC environment. The geo-object model will link GIS data-structures directly with water resources model data input needs. Close integration with GIS is an important part of DHI Software and the next generation of DHI software will interface directly to ArcView/ArcInfo so that GIS data can be used directly in and not only as an external application. The year 2001 MIKE SHE release will be the first DHI product.

Panel 1: Software Development Philosophy and Environment - Item D
Building BASINS 3.0
Russell S. Kinerson, USEPA/OW/OST

Historical Perspective

The historic reliance on the use of design flows for developing permit limits and for evaluating attainment of water quality standards has had the unfortunate consequence of leaving many TMDL practitioners ill prepared for developing TMDLs on waterbodies that receive inputs from both point sources (steady, continuous loads) and non-point sources (unsteady, discontinuous loads). Generally the episodic discharges from the non-point sources, occurring as a result of rain or melting snow, enter streams whose assimilative capacities (generally approximated as dilution ratios) are not well represented by the design flows (7Q10 or 4B3) used for setting permit limits for point sources. While determining the allowable load allocation from the non-point sources based on a design flow would be environmentally protective, it probably would neither be fair to the point source dischargers nor possible to attain under any conditions. The fact that releases from both point sources and non-point sources must be combined for TMDL purposes has further complicated the life of the water quality analyst in many states.

The easiest way to envision the necessary integration is to consider what it would be like if you could continually measure the concentrations of the pollutants of concern in the watershed. Assume that you could locate sensors at appropriate locations and collect data on chemical concentration, stream volume flow, temperature, pH, and other properties continuously (or even daily) for several years, you could develop a database that you could use to evaluate the health of the waterbody or of the watershed. With such a database, you could develop statistical descriptions of the distributions of pollutant concentrations that have resulted from the combination of PS and NPS loadings within the watershed. If you were to continue this monitoring effort for a couple decades, you could then evaluate whether or not water quality criteria (i.e., chemical concentrations) were being exceeded more frequently than specified in the State's water quality standards.

As it is unlikely that you will have either the time or money to develop such a data record for many watersheds, the next best way to generate the data needed to evaluate attainment of water quality standards is to model the watershed. By running a continuous simulation model, you can synthesize a database that is analogous to that described above. In this exercise you would simulate daily values of stream volume flow, pollutant loadings, pollutant concentrations, etc. for an appropriate period of record. The computer output from this watershed modeling study would look like the database from the monitoring study and the data would be subjected to the same statistical tests.

Loadings from point sources are based on resources such as the permitted releases of chemicals from municipal and industrial facilities (e.g., EPA's Permit Compliance System database) or from monitoring data collected at these facilities (e.g., Discharge Monitoring Reports). Loadings from non-point sources are estimated by the watershed models; the loads depend on factors such as land use, vegetation cover, and meteorological conditions. The resulting pollutant concentrations are estimated by dividing the daily loadings (total of loads from both PS and NPS) by the model generated daily stream flow. If in-stream concentrations exceed criteria, loads are reduced until standards are attained.

Based on Hydrologic Principles

A continuous simulation model was considered to be critical for a realistic representation of watershed processes. Continuous simulation models combine daily (or other time-step) measurements or synthesized estimates of effluent flows and loads, wet-weather source concentrations and loads, and receiving water flows to calculate receiving water concentrations. A deterministic model is applied to time series of these variables to predict resulting concentrations in chronological order, with the same time sequence as the input variables. This enables a frequency analysis of concentrations at a given point of interest, as will be explained more fully below.

In natural systems, flows typically exhibit correlation in time (serial correlation), so that low flow days tend to follow other low flow days, and high flow days follow high flow days. Precipitation-driven episodic loads often exhibit cross-correlation (correlation between different variables) with receiving water flow, as the same precipitation that generates the load may also increase flow throughout the watershed. Both serial and cross-correlation can have important implications for predicting water quality impacts. For instance, if episodic loads are most likely to occur when flow in the receiving water is high, an adverse impact on water quality is much less likely than if the loads occur when flow in the receiving water is low.

A continuous simulation approach automatically takes into account the serial correlation present in flows and other variables, as well as cross-correlations between measured variables, because real data are used. This is potentially the most powerful method available for accurate prediction of the frequency of receiving water concentrations, but it does have disadvantages. Notably, the method is very data intensive and may require observations over many years to accurately evaluate the frequency of occurrence of water quality excursions. Long time series of monitoring data for wet-weather loads will generally not be available and may have to be simulated from precipitation records using rainfall-runoff models. Simulating data introduces uncertainty; indeed, if good observations of time series of more than one input parameter are lacking it may be preferable to use a statistical simulation approach (such as the Monte Carlo method described below), which allows a direct analysis of the effects of input uncertainty on model predictions.

Built on Available Hardware and Software

The application known as BASINS was designed and developed to meet the needs of the TMDL program. Recognizing the need to estimate NPS loadings under various environmental conditions, and to combine them with PS loadings, a watershed modeling system with appropriate databases was integrated with a GIS platform operating on desktop PCs.

BASINS 3.0 allows the user to delineate watershed boundaries on the basis of predetermined digitized boundaries (e.g., 8-, 11-, 14-digit watershed boundaries), by subdividing watershed polygons with the aid of the mouse, or by using the power of the GIS platform to determine the watershed that contributes to a stream based on Digital Elevation Modeling (DEM). The stream network may be determined from DEM or preexisting digitized stream networks (e.g., RF1, RF3, NHD, or the Census Tiger Files) may be overlain and burned in. Once the watershed is spatially described and locations of point source dischargers, water withdrawals, and pour point of watershed established, the user can decide which of the watershed models to run to estimate the resultant effect of point and non-point source loadings to the receiving waters.

The use of raster data requires ArcView's Spatial Analyst Extension (version 1.1). New data that will be packaged on BASINS 3.0 CDs are raster 90 m DEM data and the databases that support SWAT. BASINS 3.0 will perform "on the fly" griding of existing land use and soils shape files data for use with SWAT. DEM data at 1:24,000 or other scales and the Multi Resolution Land Classification (MRLC) data may be imported and used directly in BASINS 3.0.

BASINS 3.0 provide the user with a choice of watershed models; the Hydrological Simulation Program-FORTRAN (HSPF v.12), the Soil and Water Assessment Tool (SWAT), and an export-coefficient based model called PLOAD. HSPF is well known to BASINS' users from versions 1 and 2. SWAT simulates hydrology, pesticide and nutrient cycling, bacteria transport, erosion and sediment transport. SWAT is ideally suited to predict effects of land use management (such as climate and vegetative changes, agricultural practices, reservoir management, groundwater withdrawals, water transfer) on water, sediment, and chemical yields from river basins. Both SWAT and HSPF are spatially distributed, lumped parameter models. They may be used to analyze watersheds and river basins by subdividing the area into homogenous parts. SWAT uses a daily time step for simulations running from 1 to 100 years; HSPF, as implemented in BASINS, uses an hourly time step. We anticipate that SWAT will meet many modeling needs for situations where TMDLs need to be developed for watersheds dominated by lands in agricultural operations.

PLOAD is a simple watershed model that computes non-point source loads from different subwatersheds and landuses based on annual precipitation, landuses and BMPs. Successful linking of the model to existing BASINS data and user supplied data makes the model useful in estimating non-point source loads, relative contributions and load reduction by BMPs. PLOAD requires watershed boundary, landuse, best management practices (BMPs), point sources and annual precipitation data to compute pollutant loads.

Additionally PLOAD requires event mean concentrations (EMCs) and/or loads per acre tables for different land use types.

BASINS data includes landuse coverage, point sources and watershed boundaries and also allows users to import their own landuse coverages and watershed boundaries for watershed modeling and analysis. Each of the watershed models recognizes these data sets automatically. BMP data will be provided by the user and, therefore, BASINS should allow users to import BMP data similar to other (e.g. landuse, watershed boundary, Reach file 3, etc) data sets. PLOAD also will read the same percent perviousness table used for non-point source modeling using Win-HSPF. The point source flow and loads are available in the Permit Compliance System (PCS) and Industrial Facility Dischargers (IFD) tables. PLOAD can use these data to determine the total flow and loads from a watershed.

HSPF v.12 includes a simplified snow melt algorithm (i.e., degree-day approach), the ability to model land-to-land transfers, high water tables and surface ponding (wetlands), and the addition of new BMP and Reporting modules. The new SNOW module requires only precipitation and air temperature time series, while producing essentially the same output as the current module which requires five additional meteorological time series (evaporation, wind speed, solar radiation, dew point, and cloud cover).

Generation and analysis of model simulation scenarios (GenScn), was developed by the U.S. Geological Survey (USGS) to create simulation scenarios, analyze results of the scenarios, and compare scenarios. GenScn provides an interactive framework for analysis built around HSPF for simulating the hydrologic and associated water quality processes on pervious and impervious land surfaces and in streams and well-mixed impoundments. GenScn also supports SWAT output time-series post processing. The GenScn graphical user interface (GUI) uses standard Windows 95/98/NT components. The strengths of this component have been added to BASINS and provide most of the post processing and display features.

A major redesign of the system has resulted in the use of ArcView Extensions. The increased modularity facilitates greater maintainability and ease of updates, a much smaller Asystem@ file, and a better path for the anticipated transition to ArcView 8.

Panel 1: Software Development Philosophy and Environment - Item E
Spatial Hydrologic Modeling
David R. Maidment, Director, Center for Research in Water Resources,
University of Texas at Austin

A substantial investment is presently being made by federal, state and local agencies in developing geospatial datasets to support hydrologic modeling. There are four national "hydro" datasets for the US either just completed or being prepared by federal agencies:

National Elevation Dataset (NED) – a 1 arc-second (30m) digital elevation model of the US in seamless 1º blocks HYPERLINK http://edcnts12.cr.usgs.gov/ned/ (USGS)

National Hydrography Dataset (NHD) – a 1:100,000-scale representation of rivers and waterbodies of the US divided into 8-digit HUC watersheds HYPERLINK http://nhd.usgs.gov (EPA and USGS)

National Elevation Dataset – Hydrology Derivatives (NED-H) – a processing of the NED to divide the US into about 1,000,000 elementary catchment areas HYPERLINK http://edcnts12.cr.usgs.gov/ned-h/ (USGS and NWS)

Watershed Boundary Dataset (WBD) – an accurate watershed delineation of the US dividing the 2149 8-digit HUC watersheds into approximately 22,000 10-digit watersheds and 160,000 12-digit watersheds (USDA and USGS)

In addition, the USGS National Water Information System (NWIS) has recently been released in a web-accessible form, HYPERLINK http://waterdata.usgs.gov/nwis-w/US/ and a National Land Cover Dataset was recently released, HYPERLINK http://edcwww.cr.usgs.gov/programs/lccp

The availability of these data makes spatial hydrologic modeling possible over large areas and in a degree of detail previously unattainable. To synthesize these various data sources into a single coherent geospatial data structure, the Environmental Systems Research Institute (ESRI) has joined the Center for Research in Water Resources (CRWR) of the University of Texas at Austin and a group of interested institutions and individuals in a Consortium for GIS in Water Resources to create a new ArcGIS Hydro Data Model using an object-oriented approach expressed in the Unified Modeling Language. This data model was published in draft form in June 2000, HYPERLINK utwired.engr.utexas.edu/crwr/cd_Consortium_2000/GisHydro2000.htm and is presently being finalized for publication. The national hydro datasets and the revised version of the ArcGIS Hydro Data Model will be presented at a National Hydrography Dataset (NHD) Applications Symposium to be held at the University of Texas at Austin on Dec 11-14, 2000, HYPERLINK http://www.crwr.utexas.edu/giswr/nhdconf/nationalhydro.html

A feature of the ArcGIS Hydro data model implemented in ArcInfo and ArcView 8.1 provides robust support for the first time within GIS of a water resources network model, connecting catchments, watersheds, streams, rivers, lakes, and coastlines in a linked system where the movement of water can be traced sequentially through the landscape. Each vertex along the hydro network lines is represented in four dimensions, (x, y, z, m), where m is the "measure" or flow distance along the line. Individual points are located on the network by knowing which reach they are on, and at what measure location within that reach. Catchment, watershed and waterbody areas linked to the river network are located on the network by this addressing system, which permits the discharge of water from these areas to be input to one-dimensional flow routing schemes along the river network. The stage is being set for a new generation of geographically enabled hydrologic models, which link the description of the water environment to the simulation of water movement through that environment.

Panel 2: Roles of State/Federal/University/Private Organizations - Item A
University Perspective
Jim Nelson, BYU

The Environmental Modeling Research Laboratory (EMRL) of Brigham Young University (BYU) has been involved in the development of engineering visualization software since the 1970's. The original software MOVIE.BYU was distributed by BYU for uses in scientific visualization and included source code so that it could be "ported" to other computers and operating systems. It was very successful and many of the early visualization software tools developed by commercial companies were adaptations of the MOVIE.BYU source code. As hardware and software platforms became more standardized the visualization code was converted to run under standards such as X-Windows on Unix platforms and then later to Microsoft Windows on personal computers. As the scientific community moved into the visualization arena this fruitful area of research dried up for EMRL. As a result, the core visualization routines were adapted for use with programs for hydrologic and hydraulic processes modeling. The large set of program libraries and graphical user interfaces developed for MOVIE.BYU made it possible for EMRL to make significant advances in the development of tools for pre/post processing of surface runoff models, groundwater models, and surface water models. This work has evolved into the three programs known as GMS (Groundwater Modeling System), SMS (Surface-water Modeling System), and WMS (Watershed Modeling System). These programs are distributed as executable only for both Unix and PC platforms (although in the coming years it will only be available on PC's). When distribution and support of the software became too large to handle within the lab (and within the mission of the university), an exclusive agreement between the BYU technology transfer office and Environmental Modeling Systems Inc. (EMS-I) was established to handle commercial sales and support of the software.

Throughout the history of EMRL, research has been funded as a combination of sponsored research and sales of the software programs to private industry, education (academic institutions have always received heavy discounts) and other non-sponsoring government agencies. During the past decade a partnership between EMRL and the U.S. Army Engineer Research and Development Center (ERDC) helped combine the state-of-the-art capabilities in graphics and visualization of EMRL to the analysis codes developed by ERDC. Existing EMRL libraries and visualization code were contributed to the partnership at no cost to ERDC and other sponsoring agencies. This partnership was primarily based on ERDC's desire to have a consistent look and feel to their software developments that would reside on multiple platforms. This partnership has resulted in state-of-the-art software that is directly available to ERDC partners and customers at significantly less than the cost would have been otherwise through any other development path. More recently the Federal Highways Administration (FHWA) has entered into a similar partnering agreement in order to bring the state of the art visualization and hydrologic model processing tools to federal and state highway agencies. This funding model consisting of both sponsored funds for targeted development tasks and royalty streams not tied to specific tasks has provided a consistent and flexible source of funding for EMRL. These resources have been used to fund faculty, students, and staff to develop, expand, and enhance tools that provide increased functionality to these systems, and partnering agencies by direct extension, at absolutely no cost to the government.

This model for software development has resulted in a win-win-win situation for EMRL, the sponsoring agencies, and private industry for the following reasons:

1. Sponsoring agencies have benefited by having access to powerful, state of the art modeling and visualization tools at a fraction of the true development cost. Because EMRL is motivated by the ability to sell privately its software, sponsoring agencies receive a much more polished and enhanced deliverable than would be otherwise possible for the same cost. Much of the high cost of maintaining the software and insuring that it is consistent with the latest hardware and software standards is paid for out of software sales to private industry. Sponsoring agencies are allowed unlimited distribution rights to the software (complete versions not just portions funded by the sponsoring agency) within their agency, providing that they perform distribution and support for their people. Furthermore, emerging technologies (hydrologic and hydraulic models) can be distributed to a much wider audience for testing and validation.
2. EMRL benefits by being able to fund research and development from both sponsored research contracts as well as sales from industry. Not having to worry about gaps in funding has allowed EMRL to maintain its research at a high level by hiring full time research assistants to provide experience and continuity. All of this has led to widespread exposure and recognition of EMRL's work, which has resulted in further collaborative opportunities (both government and private).
3. In general the cost of these tools to the private consultant and other organizations that must purchase licenses is less because of the sponsorship provided. These users also have better access to the models and tools being sponsored by the various government agencies.

This model for commercialization of products developed all or in part by government sponsored research is not unique to EMRL. In fact it is a classic example of the technology transfer model espoused by the government through federal legislation that is almost twenty years old. Prior to 1980 very little technology transfer was occurring from universities and small businesses because the government claimed all patents and licensing rights of products developed with government monies. This resulted in only about 2% of government patents becoming licensed. The Bay-Dole Act of 1980 turned the patent and licensing rights over to universities and small businesses (less than 500 people) for all products developed with government sponsored research dollars. The enactment of this legislation has resulted in a dramatic increase in technology transfer. Today approximately 50% of patents are licensed for development. Furthermore, by providing incentives (a royalty stream) for the researchers at universities to stay involved, there is a greater likelihood of developing a successful product and enhancing it over the years.

Panel 2: Roles of State/Federal/University/Private Organizations - Item B
Federal Perspective
Mike Smith, National Weather Service

Question 1. What, if anything is wrong with the status quo in developing, distributing, maintaining, supporting, and training users of hydrologic process models?

First, there seems to be some overlap in the development of new models. Research and development is often done in parallel without coordination. Another problem is providing support for users. Our primary mission is not to provide software to the public. However, we should make a reasonable effort to promote the spread of technology if there is interest. Yet, due to funding levels, there is little we can do beyond a limited level (at least in the NWS) to provide support for software when is it is used by others. Also, a specific process model may not be easily shared with others because the structure of the execution routine is often linked to the data format or system architecture.

Question 2. If the status quo is non optimal, what is the best role for your sector in the ideal world of hydrologic modeling?

In an ideal world, there could be more collaboration in model development. This need not be a formal mechanism, but rather collaborative projects in which the main participants are scientists. Model intercomparison studies would be beneficial, with efforts such as SnowMIP and DMIP perhaps being examples of efforts that promote scientific exchange.

Question 3. What obligation, if any, does the federal government have to share information with the other sectors (private, academic, etc)?

The Federal Government does not have a specific obligation to freely share software or information. However, there should be a reasonable effort to provide good scientific models to the public.

Other issues surrounding the distribution of software developed by the Federal Government are very complex. In general, the Copyright Act doesn't permit the government to copyright software developed by the government/government employees. The Freedom of Information Act (FOIA) and the Paperwork Reduction Act laws all apply, as well as OMB Circular A-130. There is little the federal government can do to protect software from being repackaged and sold. Perhaps the most that can currently be done is to complain about misrepresentation of the authors or developers. Also, there are no easy ways to track Government funded software. Software developed by the Federal Government can be sold by others, but not copyrighted by others unless there is some value added to the code.

Other guidelines:

a. If the software is patented, then whether or not the software is in the public domain depends on the decision of the agency.

b. For development under CRADAs (cooperative research and development

agreements), software developed by Government employees is in the public domain. Software developed by the non-Government participant is privately owned.
c. Software developed under grants is owned by the 'grantee' unless the grant specifically says otherwise.

A bill has been sent to the President for signature that grants the Federal Government limited authority to protect its software. The bill would authorize the licensing of software without it being patented. However, there appears to be little enforcement ability.

Question 4: What opportunities do you see for better cooperation and information sharing with the other sectors represented by your fellow panelists?

More workshops like this would be a good start. On a large scale, specific programs could also be an opportunity for better cooperation. For example, the Science Infusion component within the NWS Advanced Hydrologic Prediction Services (AHPS) initiative could provide funding for targeted projects. Model comparison studies such as the Distributed Model Intercomparison Project (DMIP) should provide forums for meaningful scientific exchange. On a smaller scale, newly established list servers for specific NWS software have provided a vehicle for non-Government users to post questions for anyone to answer. Non-Government users can also email questions directly to the NWS, but resource limitations can sometimes delay the ability to answer. Other Federal agencies offer short seminars to address specific user problems.

Panel 2: Roles of State/Federal/University/Private Organizations - Item C
Tony Donigian, AQUA TERRA Consultants

Before stating my views on the panel topic, I feel I need to briefly describe my background in this area to provide a reference for my opinions. I have been involved in watershed hydrologic and water quality modeling for about 30 years, working for various private consulting firms primarily on government contracts for U.S. EPA, U. S. Geological Survey, U. S. Army Corps of Engineers, and various state/local agencies. My work has been associated with the family of models derived from the Stanford Watershed Model, i.e., the Hydrologic Simulation Program Fortran (HSPF), associated software products from the USGS, and most recently, the incorporation of HSPF within the EPA BASINS system. I have had little or no involvement with proprietary software, as most of my work has been for public agencies and producing public domain models and programs.

My experience with HSPF and related software involved working through three different private consulting firms, doing model development, enhancement, application, maintenance, and training. My firms were never involved in code distribution as that was handled by EPA and USGS. This has been an experience and example of federal-private cooperation, working for both agencies, and our efforts have helped to (1) produce a better overall product for model users, (2) maintain the integrity and stability of the code, (3) facilitate cooperation among the various agencies, and (4) ultimately benefit model users by the continuity of the model development and support. ALL three agencies - EPA, USGS, Army COE - currently support and use HSPF. As noted above, EPA promotes HSPF for use in selected TMDL (Total Maximum Daily Load) efforts through it's BASINS program, the USGS has support developed various support programs including a GUI, called GenScn, for evaluating watershed scenarios, and the Army COE has recently implemented HSPF as the watershed water quality model in its Watershed Modeling System (WMS).

In addition, the policy of the development effort has been that ALL enhancements would remain in the public domain, and be available to all users in subsequent releases of the code. HSPF was first released in 1980 as Release No. 5, and Release No. 12 will be issued in early 2001; it will be included in the BASINS 3 version to be released concurrently. Various outside agencies abided by this policy and provide funding for code enhancements, including the Chesapeake Bay Program, the Minnesota Pollution Control Agency, the South Florida Water Management District, and selected counties and Army COE districts.

Clearly, not all environmental model development follows this path, nor should it be the only way. I don't feel the current status quo of modeling and model development, support and training is all that bad, i.e. I don't feel there is anything inherently **'wrong'** with the current system. There are definitely roles for federal, university, state and private groups, and the roles are not likely to be preordained, but will likely evolve over time as determined by the needs of the individual groups and both internal and outside model users. However, I do believe there is a continuing role for federal agencies in support of model development, user support, training, and maintenance. In addition, the modeling community and user community need to focus on the ways and means of stabilizing funding for model improvements, developing model comparisons and evaluations as a basis for model selection, preparing guidelines for model application, including calibration/validation procedures which should include a range of recommended graphical and statistical procedures for comparing model results with observations.

In this environment of easier and easier to use GUIs for both simple and complex models, there is a real danger of model mis-use and abuse, by novice and experienced users alike. Pursuit of the topical areas noted above may help to forestall continuing misuse of models, and potential environmental disasters and waste of resources resulting from improper model applications and interpretation of model results. Perhaps, the federal role should be implemented through an inter-agency task force, and/or establishment of modeling 'centers of excellence' to support, guide, and nourish the use of models in the arena of water resources and environmental assessment.

(Note: For references and related information, please visit AQUA TERRA Consultants web site, www.aquaterra.com).

Panel 2: Roles of State/Federal/University/Private Organizations - Item D
Private Software Distributor - Developer
Saša Tomic, Haestad Methods, Inc.

Introduction

This paper gives a summary of private software developers views presented in Panel 2, "Roles of State / Federal / University / Private Organization," of "Hydrologic Process Modeling" Workshop. The paper is divided in two sections. The first section gives an overview of Haestad Methods, Inc., a private hydraulics and hydrology software developer that represented the views of Private Organizations at the panel. The second section of the paper gives answers to the questions posted to the panel. The author feels that this organization of the paper will help the reader to better understand the views expressed in the second section.

Haestad Methods in Brief

Haestad Methods, Inc. (HMI) is one of the few, if not the only company, devoted entirely to hydrologic and hydraulic (H&H) software development. With more than 20 years of experience in H&H industry and millions of dollars per year investment in research and development (RaD), HMI is the world-leading provider of H&H modeling applications. More than 100,000 customers in almost every country on the globe use Haestad products. Autodesk has chosen HMI as the "Preferred Hydraulics and Hydrology Solution Provider." HMI has very close ties with Environmental System Research Institute (ESRI). Strategic partnerships with World's leaders in CAD and GIS industry allow HMI to provide clients with solutions that cover every aspect of the water resources modeling, from data collection, analysis and preprocessing to result representation and distribution.

HMI started in 1979 with conversions of FORTRAN-based mainframe models to PC platforms and development of user-friendly interfaces. HMI developed its first proprietary program, PondPack, in 1987. Today, PondPack is the most commonly used software for the urban stormwater management. Two years later, Haestad extended its business to Continuing Education and Training. Since 1989, HMI has trained over 6,000 engineers in 100's of IACET and PDRES-accredited workshops in the USA and internationally. Today HMI offers a suite of CAD and GIS-integrated programs ranging form rainfall-runoff modeling to water distribution and wastewater management software developed, using cutting-edge object-oriented development and design techniques; Haestad Press publications are used by the majority of ABET accredited universities in the USA and numerous institutions worldwide; Haestad hosts CivilProjects.com RFP and RFQ exchange site, publishes Current Methods magazine, and sponsors numerous conferences, to mention just a few of HMI services to the community.

Roles of Private Software Developers

What is wrong with the H&H software industry?

Compared to the other segments of software industry, contemporary H&H software industry is doing well. However, there is always room for improvement. More information exchange about algorithm and software development, especially between government agencies, would benefit everyone, above all the end users. Introduction of standards for approval and comparison of algorithms and programs used in hydrologic modeling would help the users in the selection of appropriate tools as well as developers in the validation of their models. Finally, institutionalization of common modeling platforms and/or data exchange formats would facilitate coupling of the existing models.

What is the best role for Private Developers?
The business of private developers is to provide end-user solutions. To ensure the best products, the primary role for private developers is in the continuous H&H model development and enhancement, user training and education, providing technical and engineering support to the end-users, incorporating new technologies and algorithms into H&H models, and offering the support for new operating systems and modeling platforms.

What obligation do Private Developers have to share information with others?
Private developers work with the end users on a day-to-day basis. Their key obligation in information sharing is towards the customers. The customers need to be informed about the newest trends in H&H industry as well as about the changes in the models they are using. At the same time, the flow of information should go the other way. The developers need to collect information form the end-users about the feature requests and model usability demands. Private developers should share this information with other players in the H&H software industry.

What opportunities lie in the future?
Newest advances in WWW technologies (XML, XSL, XSTL, SOAP, etc) have opened the doors for simple and efficient data exchange between H&H models. In the future, H&H models will be able to search the WWW for data needed to run a model and use the most current information for every model run. XML (eXtensible Markup Language) will be used to describe and package data that will be easily transferred across the wire using SOAP (Simple Object Access Protocol). Validation of the data in XML files will be achieved using XSL (eXtensible Stylesheet Language). Mapping between incompatible XSL formats will be accomplished through XSTL (eXtensible Schema Transformation Language). The tedious data transformations needed today to couple H&H models will be forgotten things of the past.

For more information about Haestad Methods, Inc. visit www.haestad.com.

Panel 2: Roles of State/Federal/University/Private Organizations - Item E
State Perspective
Sushil Arora, California Water Resources

Q1: What, if anything, is wrong with the status quo (the current roles of state/federal/university/private organizations in developing, distributing, maintaining and supporting, and training users of hydrologic-process models)?

1. Currently, in my opinion, software developed through government funds/grants by University or private organizations tend to become proprietary The proprietary nature and possibly patents, stifle the growth and evolution of models. Modeling, and model development, is not a process performed in a vacuum. Past modeling development efforts provide the starting point, or learning tools, for future model development. Restricting access to models, particularly ones developed with public funds may limit the directions of future model development.

2. In addition it seems that many models developed with public money lack full and thorough documentation for an end user. There is also lack of training for appropriate use of models.

3. When models developed by different agencies for the same prototype provide inconsistent answers for the same questions, stakeholders and decision makers loose confidence in the use of models for providing them unreliable information. There should be a set of modeling protocols which must be adhered to by the model developers.

Q2: If the status quo is nonoptimal, what is the best role for your sector (state/federal/university/ private) in the ideal world of hydrologic modeling?

1. In my opinion, most model development will continue to be done by universities and public agencies with assistance from private entities. Copyrighting of software tools under General Public Licenses guarantees that the product cannot simply be redistributed by private entities for a profit and allows complete public access to the product. By making the product widely available, improvements will be made by people who would not otherwise pay for the product. Development and maintenance will continue to be done in the universities and public agencies. Private firms may provide significant improvements to the model in terms of front-ends, support, and training.

2. Use of the internet may be an excellent alternative for disseminating models and associated data, including self-guided tutoring on the use of models. Classes are also very helpful, though time-consuming.

3. The models must go through a peer-review process. This will advance the model's acceptance and understanding by the user community, including stakeholders and decision makers.

Q3: What obligation, if any, does your sector have to share information with the other sectors (and with the end-user)? For example, do government developers have an obligation to share freely their algorithms with private developers? Can private developers charge licensing/support fees for products developed all or in part from governmental sponsored research and development contracts?

1. State of California's Department water Resources has full obligation to share Hydrological Models developed by its modeling staff, share data and algorithms along with associated documentation to all the public including private consulting companies. We provide this information on our WEB site. As and when needed, private engineering companies are contracted for any special services for the modeling program.
2. Yes; private developers should charge nominal fees for their services, as long it does not hinder the growth and evolution of models.

Q4: What opportunities do you see for better cooperation and information sharing with the other sectors represented by your fellow panelists?
1. Closer collaboration between State, other local and federal agencies and the universities would provide benefit to our overall modeling program. This will also help us in our efforts to recruit more qualified staff to our modeling group. It is noted that for last couple of years State and Federal agencies (namely DWR and USBR) in California have been collaborating to develop a Joint-Model for the Central Valley of California for use by both agencies for their planning effort.
2. Establishment of a Model user group that is open to interested agencies and stakeholders and private consultants will be very conducive to provide feedback to model developers.

Panel 3: Appropriate use and Guidance for use of models - Item A
South Florida Water Management District

Jayantha Obeysekera, Director Hydrologic Systems Modeling Department,
South Florida Water Management District

Modeling provides a way, perhaps the principal way, of predicting the future behavior of existing or proposed water resource systems (Loucks, 1990). Hydrologic models are becoming an increasingly important source of information, but such information is never complete, and is rarely, if ever, certain. Hence, they should never be a substitute for the judgement of experienced hydrologists/scientists and/or decision-makers. Unfortunately, due to variety of reasons, the "model" often becomes the panacea for difficult questions associated with many water resources projects. Although there is an abundance of literature on the "guidance for use of models" the advice is often not followed. Perhaps due to recent advances in computer technology and the development of "easy to use" simulation models, there is increasing evidence of model misuse of models by users who lack even the basic knowledge and experience of applying hydrologic simulation models. This presentation is intended to provide a catalyst for the discussion of appropriate guidance and the use/misuse of hydrologic models in current practice.

Table 1. Common mistakes in hydrologic modeling and some suggested solutions

Category 1: Improper "conceptualization" of the hydrologic system	
Common mistake	**Potential solutions**
• Misunderstanding of the problem • Omission of relevant physical processes • Improper "degree of conceptualization" (black box vs. physically based) • Selection of inappropriate model geometry • Improper specification of model boundaries and boundary conditions • Wrong assumptions related to heterogeneity in the system • Lack of attention to and/or understanding of scale issues (both spatial and temporal) • Lack of attention to data availability	• Development and the publication of Standard Practice for Hydrologic Modeling (e.g. ASTM) • Well-designed studies of model comparisons to develop general application guidelines (e.g. WMO, 1975) • More training programs for all (federal/state/local) by leading agencies and academic institutions involved in modeling • Better availability of common data sets
Category 2: Selection of inappropriate computer code	
Common mistake	**Potential solutions**
• Selecting a code more or less powerful/versatile than what is necessary • Being driven primarily by "bells and whistles" • Selection of a code that has not been	• Certification of models for various applications (e.g. FEMA) • Establishment of a Clearing House for disseminating models and their application. • Encourage modelers to send in or post

"verified" or tested • Use of a code that is based on improper mathematical models for simulating the real-world physical processes in the specific problem (e.g. using kinematic wave model when backwater effects are present) • Lack of local experience in applying the model • Lack of proper documentation • Lack of knowledge regarding solution algorithms and the internal structure of the model	on the internet their experiences in applying the model using a standard reporting format • Increased attention to the development of "analytical solutions" and their use for verification of numerical models • De-emphasize the "ease of use" factor • Proper education of students in all disciplines (hitting a "button" to get the answer is not the proper way) • Encourage documentation and the sharing of the documentation via the clearing house • Require the developers of the certified models to submit the limitations of the models and the suggestions on appropriate and inappropriate applications of his/her model
Category 3: Improper model application	
Common mistake	**Potential solutions**

• Selection of improper values for model parameter and input data
• Mistakes made in the selection of temporal and spatial scales
• Making prediction with a model that has been calibrated under different conditions
• Absence of and/or limitations in "calibration"
• Lack of "calibration and predictive sensitivity analyses
• Lack of uncertainty estimates of the prediction
• Lack of basic checks on the output (e.g. mass balance)
• Unfamiliarity with the process assumptions used to develop the model
	• More investigations of the proper selection of spatial and temporal scales, and the associated numerical errors
	• Development and publication of a Standard Practice for:
	  ◦ model "calibration" and the pitfalls
	  ◦ calibration and predictive sensitivity analyses
	  ◦ estimation of predictive uncertainties
	  ◦ reporting requirements (e.g. require submission of a statement of uncertainties along with model output)
	• A professional certification program for modelers
	• More training programs

Category 4: Misinterpretation of modeling results	
Common mistake	**Potential solutions**
• Wrong hydrologic interpretation of model results by analysts who lack experience • Gross extrapolations • Lack of attention to model accuracy and the uncertainty estimates of the	• Professional certification of those who help interpret modeling results

predictions • Wrong application of the model when the model is not designed or capable of such applications (use of water supply models for addressing flood control issues) • Misuse of results by partial representation	

Panel 3: Appropriate use and Guidance for use of models - Item B
Natural Resources Conservation Service
William Merkel, Hydraulic Engineer, NRCS

Introduction:

The NRCS (formerly SCS) has been involved in developing and using hydrologic computer models since the 1960's. Naturally, the models have increased in sophistication as both the basic research and computing equipment evolved. The philosophy of the agency has been to develop models to be used in planning, design, and operation of projects to conserve water and soil resources and protect their quality. Over the years, much experience has been gained in developing models, supporting and maintaining them, and training users. The major uses of hydrologic models in the NRCS are for watershed and field scale applications. At a larger scale, models are used for flood protection projects, rehabilitation of aging dams, flood plain management studies, water quality evaluation, and water supply forecasting. At the field scale, models are used for many varied purposes such as planning and designing soil conservation practices, irrigation water management, wetland restoration, stream restoration, and water table management. Models developed and used by NRCS are being used by other federal, state and private organizations (and vice versa, NRCS is using models developed by others). That NRCS models are being used by others may be viewed as positive by considering that the models fill a need and the users voluntarily select them. The reasons are most likely varied but may include simplicity, usability, utility, data availability, and validity.

NRCS relies on research completed by the Agricultural Research Service, other federal agencies, and universities to use as the basis of hydrologic models. In developing models, the following issues need to be considered (not listed in order of importance).

1. What is the critical need for the model ? What resource problems will the model address ?
2. Will the research or mathematical model address the range of applications of potential users ? What are the limitations and assumptions ?
3. Are data for the model readily available or easily derived ?
4. Who are the potential users ? What is their level of expertise ?
5. How will potential users be involved in model design including developing input requirements, desired output, terminology, software testing, training plans ?
6. Who will develop and support the model ?

Questions for Panel 3

The questions brought up by the workshop attendees are very thought provoking. Without addressing each one individually, the large majority of the questions have been dealt with by the NRCS in its history of computer model development and support. There have been bumps along the way and it has taken time to learn an acceptable way to develop and support a hydrologic model. So many of the questions may be addressed differently depending on the purpose of the model, who the users are, who the support staff is, etc. The fact that the questions have been dealt with does not imply they have been completely successful or that a plan or universal solution to the question has been found. Further discussions at this workshop and following conference concerning standardization, cooperation, and user qualifications will be extremely valuable.

Current NRCS Efforts

Two current efforts will be described which address some of the questions raised by the workshop attendees. One of these is the evaluation of water quality models. Early in the year 2000, a team of national level modeling experts was assembled to investigate the array of water quality models which are used to evaluate agricultural non-point source pollution problems. The impetus of this effort was that the NRCS management wanted to develop a model or small group of models which would be supported to large numbers NRCS users. Management realized the scope of national model use and was considering ways to support models, commit staff for an expert support team, provide training, develop documentation, etc (realizing also there are limited resources). Management instructed the team to first list the models to be considered, then develop a matrix of model components and the relative technical level or sophistication of the various models as pertaining to each model component. These comprised the first two steps of a five-step evaluation process. Additional steps will include: Step 3 - screen the models for selected criteria, Step 4 - technical evaluation of models selected in step 3, Step 5 – prioritize models and develop a technology transfer support plan. As part of Step 3, to involve model users in the selection process, the NRCS water quality specialists in each state were recently polled. A number of questions were asked, including what are the important water quality issues and which models they currently use or would like to use. The desired outcome of this process will be a set of models to meet NRCS user needs and be documented, tested, supported, and comprehensive training opportunities offered.

The second major effort currently in progress is a Partnership Management Team (PMT) formed to coordinate research and technology development among the USDA agencies (ARS, NRCS, and CSREES). This team involves the research and technology management level of the three agencies including those who can make priority, staffing, and funding decisions. One of the functions of the team is to organize the varied requests for research and technology from the employees who work directly with land managers in the field. Another function of the team is to plan the organization needed to complete the research and develop the technology then deliver it to the users.

Conclusions

Despite the amount of experience NRCS has with model development and support, much more could be done. With technology development and support, we often look at the short term solutions (the "putting out fires" approach) instead of long term planning which addresses future user needs for models, completing relevant research, developing complementary models, automating input data operations, and building user expertise. However, there is sometimes a disadvantage to long term planning in that projects which are envisioned whose scope is too large may suffer when staffing or funding are removed or the need of the technology or the technology itself becomes obsolete. In NRCS, technology development needs to involve both users and management to successfully deliver and support the technology to address the water related problems of the nation.

Panel 3: Appropriate use and Guidance for use of models - Item C
Hydrocomp, Inc.
Norman H. Crawford, Hydrocomp

In *Elements of Applied Hydrology* written in 1949, Johnstone and Cross wrote; "to be able to examine a topographic map, perhaps walk over the ground, and then predict the flood regime of an ungaged drainage area --- that is at once the grand dream and the despair of hydrologists"[1]. A half-century later this comment still applies, if the word "predict" is replaced by "model".

Model development and model usage are distinct activities. Model developers and model users have a symbiotic but adversarial relationship. From the viewpoint of model developers, model users need a lot of guidance in appropriate use --- they need education, attention to detail, and awareness of modeling uncertainties. From the viewpoint of model users, model developers are not providing adequate tools --- they have not fulfilled the "grand dream".

How then to proceed? Since the title of this panel is "appropriate use and guidance for use of models" this is a starting point. Comments about model developers are limited to those aspects of model development that contribute to appropriate use.

Model Efficacy and Accuracy

Model users must be aware of model efficacy: Does the model produce the intended results? Is the accuracy of results appropriate for the application? The parallel obligation for developers is to provide information on modeling efficacy and accuracy: Documentation should show the processes that are represented in the model and the algorithms or methods that are used[2]. Developers need to provide guidance and methods to help users estimate model accuracy.

How can model accuracy be estimated? Calibration for model parameters, verification of calibration, and sensitivity analysis for the effects of parameters on results are needed. There must always be a means to estimate accuracy even for ungaged basins, e.g., What accuracy does the method achieve when applied to nearby gaged streams?

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[1] Johnstone, D. and W. P. Cross, Elements of Applied Hydrology, The Ronald Press Company, New York, 1949, pp. 212

[2] Model algorithms and methods can be published even for proprietary models. Hydrologic models include extensive infrastructure --- data management and user interface code that need not be published.

Education for Model Users

There is no instant remedy for lack of education or experience. Training in hydrology and hydraulics allows users to learn models more quickly and use models more successfully. A model user who can select an appropriate model and evaluate its accuracy for an application is in all likelihood educated or experienced.

A 'model' is not a panacea. Dominic Ditoro of Manhattan College often asks, "Is it the violin or the violinist?" If I were given a Stradivarius I would not expect an invitation to play a Carnegie Hall. Inappropriate use of hydrologic models may be an unavoidable consequence of recent technological developments, but steps that could help inexperienced model users and reduce the misuse of models are;

- Technical conferences on hydrologic modeling where sufficient time is available for users to explain and discuss successful and unsuccessful model applications.
- Grants for hydrologic modeling classes in universities, and encouragement for modeling classes sponsored by professional societies.
- Modeling review or oversight boards

Oversight boards are a traditional in medicine. A recent AMIA Workshop discussed the role of Software Oversight Committees to promote "responsible monitoring and regulation of clinical software"[3]. The problems that we have distributing and using hydrologic software successfully are not unique to our own specialty.

Future Directions

Hydrologic modeling has progressed and expanded enormously in the last thirty years but it is still a developing art. The sentence that follows the above quote from *Elements of Applied Hydrology* begins "the problem (of fulfilling the Grand Dream) is almost infinitely complex . . .". This remains true, and will continue to be true in another half century.

One might expect that modeling a problem that is "almost infinitely" complex would require models that are almost infinitely complex, and that future mega-computers operating on near infinite numbers of physical elements would finally solve the problem. I don't think this will be the solution. As the number of physical elements increase, the parameters needed to define these elements also increases. Dave Dawdy wrote a paper years ago that argued that the number of model parameters that can be calibrated by comparing simulated and observed variables is very limited. For hydrologic models, more can be less.

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[3] Session W3, Software Oversight Committees, American Medical Informatics Association, 1999 Annual Meeting (http://medicine.ucsd.edu/f99/E001368.htm)

Model developers and model users each have their own axioms. Developers and users are linked only by the impossibility of separation. I do not expect that the ideal hydrologic model as defined by model developers, and the ideal hydrologic model defined by users, will converge. Developers want flexibility, frameworks in which many different algorithms can be tested, more and better field data and continuing innovation. Users want simplicity, stability, and easy to use.

We might well consider two categories of hydrologic models; research and development models, and end user models. It would be idealistic to believe that research models would be released to end users only if they are restructured to meet end user needs, are proven effective, are fully documented, and are error free. Still, recognition of the differences between research models and end user models would be useful.

Panel 3: Appropriate use and Guidance for use of models - Item D

Oregon State University
Wayne C. Huber, Department of Civil, Construction, and Environmental Engineering

My experience is that most users don't read or don't concern themselves with disclaimers and notices about qualifications to use models, etc., especially if the models are "free." For instance, we recommend that SWMM users should be trained civil or environmental engineers familiar with the physical and environmental processes being modeled. Many users aren't. This is eminently clear from some of the questions asked on the swmm-users* discussion group – which along with hec-users, hspf-users and wasp-users is an invaluable resource for stormwater modelers. I cannot think of any way to control the use of public-domain models or any models that are sold openly by vendors, short of draconian legal provisions that would be "worse than the disease." Another impractical option is to allow only the vendor to actually operate the model, that is, require that the client only use the model through the model developer. Most clients want their own personnel to be able to run their own copies of models, eventually. On the other hand, recommendations to use trained consultants (to assist the potential user) might be a good idea. Let the consultants themselves provide credentials to the client to justify this trust.

As model developers, we ought to emphasize the necessary qualifications to use the model successfully, in bold type at the beginning of the documentation, as well as to emphasize the possible consequences of misuse or inappropriate use of the models. I wonder if this is less of a problem for proprietary models for which the vendor is more willing to stand behind and train potential users simply as good business practice, whereas federally developed and maintained "free" models cannot be supported in the same way. Do you get what you pay for?

Basic courses in hydraulics, hydrology and preferably open channel flow would seem to be the minimum requirement to make sense of hydrologic and hydraulic models, with more required for water quality models. Such a list should be provided in the introductory model documentation, as a guide to the user. We often see non-engineers or otherwise unqualified users of SWMM. In many cases it seems to work out OK, but frequently it is a waste of the users' time as well as that of the rest of the SWMM support community to help train them not only in how to use the model but also in learning some of the fundamental principles of water resources engineering. I see the same thing happening for users of HEC models, HSPF, and WASP (on the basis of the Internet discussion groups). On the other hand, forum members typically generously donate support.

So I conclude that it is not possible, or at least not practical, and probably not even desirable to somehow limit access to models only to qualified users. However, there are several ways in which we modelers can be more helpful to the user community and provide guidance to mitigate some pitfalls encountered by inappropriate use of models.

These ways include:

- Provide clear caveats about model limitations, in addition to statements about what the model may be used for. Adopt fonts and typesetting that **emphasize** these caveats.
- Make honest recommendations for alternative models that may do a better – or simpler – job.
- Provide clear statements about the level of experience/training expected of model users and possible consequences of a lack of such experience/training.
- Try to impress upon the user that he/she is ultimately responsible for the outcome of use of the model, even though this is probably already stated on the shrink-wrap.
- Encourage prospective users to get in contact with current users of the model for an independent assessment of the likelihood of successful application by the new user and/or success in the model's proposed application. The University of Guelph discussion groups* are an excellent resource for at least four water modeling groups. They also provide invaluable feedback to model developers regarding bugs and useful enhancements.
- An alternative for inexperienced modelers is to hire a consultant to do the job. My opinion is that the choice of the model user is more important than the choice of the model itself.
- Emphasize that the model results should make sense. Use good engineering and scientific judgment above all else.
- Provide good user's manuals with examples, not just information on input/output and theory. Identify common underlying techniques used in the model. For instance, if the model is another enhancement of NRCS methods, say so. The manuals should include help with parameter estimates, estimates of effort required to use the model (both in learning and in application), and an estimate of effort needed to assemble data.
- Continue to put more and more data (hydrologic, water quality, and especially parameter estimates) and documentation on the Web! Provide links to case studies.
- Provide enough funding for federal agencies so that they can provide direct support to users, not just develop the software. For instance, federal sponsors rarely respond to questions posed on the University of Guelph forums. Encourage federal agencies to talk more to each other. They are frequently involved as model developers, sponsors or sustainers.
- Encourage workshops and Internet forums. Facilitate interaction among model developers at meetings such as this Hydrologic Processes Modeling Workshop to discuss common problems and issues. There is a natural tendency to reflect somewhat of a closed posture toward peers simply because of business and professional competition. But there are always many useful experiences that we are willing to share.

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*Several modeling-related Internet discussion groups are operated by Dr. William James of the University of Guelph, Ontario including swmm-users, hec-users, hspf-users, and wasp-users. The discussion content is generally much broader than just arcane modeling questions and the membership seems highly inclined to help with any question. For instance, to join the free swmm-users discussion group, send an e-mail message to: listserv@listserv.uoguelph.ca. Leave the subject blank. The body of the message should contain only: *subscribe swmm-users* followed by your *name*. You will then receive copies of any messages sent to: swmm-users@listserv.uoguelph.ca.

Panel 3: Appropriate use and Guidance for use of models - Item E
Texas Water Development Board and Lower Colorado River Authority
Quentin Martin, Chief Water Resources Planner, LCRA

Introduction

The purpose of this discussion is to relate the author's experience in model hydrologic modeling, particularly with regard to user guidance, while serving in the past as a staff member of the Texas Water Development Board (TWDB) and presently as a water planner at the Lower Colorado River Authority (LCRA). The TWDB is the agency of the State of Texas charged with planning for the future water needs of the state, while the LCRA is a state-chartered regional water conservation and reclamation district.

As background, the TWDB began in 1967, with grants from the Federal government, to develop and apply a variety of hydrologic simulation and optimization models. Over the next several decades, the TWDB staff and consultants created some 15 computer-based, hydrologic models for:

- Single and Multiple Reservoir Monthly and Real Time Operation,
- Groundwater Flow,
- Canal and Pipeline Design,
- Watershed Runoff,
- Estuarine Hydrodynamics and Salinity Transport,
- Surface Water Systems Capacity Expansion, and
- Riverine and Reservoir System Water Quality.

As long as federal funds were available and executive management at TWDB was supportive, the agency dedicated staff and supplemental state funds to create models for technologic transfer as well as internal use. However, when such funding was not available or not sought, the TWDB dropped its role as a public agency with interest in research and development of modeling capability. Some model development continued, but the intended users were TWDB staff and not the water resources community at large.

Since the late 1980's the TWDB has not undertaken and applied any significant new hydrologic modeling efforts even for internal use.

Use of TWDB Models

Although used extensively in the 1970's and 1980's, TWDB models have been relatively little used over the past decade. Why? Primarily, the models are batch process programs with cumbersome input and output formats. The TWDB has not upgraded the programs to Windows or other graphical user interface software. It continues to provide those models to the public at a nominal reproduction cost, but with virtually no other support.

Since there was no concern regarding use of models outside of the agency, the TWDB did not attempt to screen prospective model users to determine if they had the knowledge or experience to use them properly. Similarly, there was minimal user support. What support there was came from dedicated individual employees who were willing to answer questions concern the individual models they created. There was very limited effort to inform model uses of errors in the code after software launch. Again, the only effort was on the part of staff who developed the models and wanted to see them successfully applied for their own personal professional satisfaction.

In addition to lack of user support, there was no attempt to make the software compatible to hardware platforms other than the computer systems used by the TWDB. This caused the failure of a number of potential model applications outside the agency.

The TWDB models are still available and have been modified in a few cases by others to Windows programming environments.

The greatest legacy of the TWDB modeling effort has been the use of the modeling concepts in the current generation of multiple reservoir simulation and optimization models, particularly the application of network flow optimization.

The TWDB SIMYLD-II single period, reservoir system simulation model is the direct ancestor of the MODSIM model developed by Colorado State University and extensively use around the world.

The PRM model developed by the US Army Corps of Engineers Hydrologic Engineering Center draws heavily on concepts used in the TWDB AL-V multiperiod network optimization model for reservoir systems.

Use of LCRA Models

The LCRA has undertaken limited hydrologic modeling efforts to meet its internal needs for automated decision support system. These projects, including hydropower optimization and flood flow forecasting, were intended from the beginning for use only by LCRA engineers and operators.

How Has TWDB Provided Guidance in the Appropriate Use of TWDB Models?

The TWDB did provide for some guidance for the use of its models by external users through the development of extensive program documentation and users manuals. These were somewhat standardized at the beginning of the modeling work. However, the level of detail in the manuals varied depending on the effort of the programmers. There was no extensive quality assurance/quality control on the preparation of the models, in contrast to the careful scrutiny received by major reports produced by the agency.

Lessons Learned

Given the TWDB experience and its original intent to be providing state-of-the-art hydrologic models, what might be the ideal program for helping users understand model capabilities and limitations, and providing effective guidance and support?

Such a program should include dedication of resources by the organization developing the model or private sector vendor to:

- Train users,
- Provide hotline/on-line user support,
- Develop automatic tutorials for self study,
- Document extensive case studies using the model,
- Organize user forums to encourage users interaction and information exchange,
- Provide internal program documentation and extensive help functions, and
- Prepare, test and disseminate model corrections and improvements to model functionality.

Panel 4: Measures of Models' Performance - Item A
University of Georgia
George Vellidis, Biological & Agricultural Engineering Department

Which agricultural non-point source water quality model is the best option to meet your needs? What new models are available that I may not be aware of? What modifications and new versions are available for my favorite model? Are new user interfaces, general data-bases, or other time saving devices available for a model, which will help me, meet the need for my application?

Consistent and comprehensive model evaluations are a continuing need considering the wide variety of potential applications and the number of models in existence. New applications create additional concern because no model is designed to meet all the needs of students, researchers, extension agents, regulatory agencies, planning organizations, consultants, and environmental groups. If models are to see truly practical and wide-spread application, the following are essential: (1) what is the original purpose of the model?; (2) under what conditions will it perform correctly?; (3) what accuracy can be expected under the best conditions?; and (4) what are the limitations?
In 1997, the following three organizations:

* MULTI-STATE PROJECT S-273: Development and Application of Comprehensive Agricultural Ecosystems Models
* ASAE TECHNICAL COMMITTEE: SW-21 Hydrology Group
* ASCE, ENVIRONMENTAL AND WATER RESOURCES INSTITUTE, Water Quality and Drainage Technical Committee

began an effort to evaluate widely used non-point source water quality models. The primary purpose for that effort was to consolidate information so that a potential user could choose the best model for their application. Model evaluation criteria were developed and scientists associated with these three organizations evaluated the following models:

AnnAGNPS
DRAINMOD,
RUSLE Soil Erosion Model
ANSWERS-2000
EUTROMOD
GLEAMS Model
WAVE
TOPMODEL
RZWQM
QUAL2E
MIKE SHE
SWAT
SIMPLE
WEPP

An abbreviated version of the criteria is given immediately below. The extended criteria can be found on the URL provided at the end of this document.

MODEL EVALUATION CRITERIA

I. Model Use Characteristics
- A. Intended Uses/Purpose/Objective of the Model
- B. Target audience: modelers/novices/agencies
- C. Verified applications
- D. Interpretation
- E. Input/Output

II. Model Characteristics
- A. Source and Availability of Model
- B. Continuing Education/Training opportunities for model users
- C. Versions
- D. Interfaces
- E. Input/Output Options
- F. Data requirements
- G. Methods (general description - Underlying solutions)
- H. Calibration
- I. Sensitivity of model results to parameters

III. Known limitations and applicability of the model
- A. Designed for particular soils or physiographic regions
- B. Known situations or scenarios the model where the model should not apply
- C. Range of testing where one should be most confident with the results

MULTI-STATE PROJECT S-273 is in the process of developing a document that includes an overall description of model evaluation efforts, the model evaluation criteria used for each model in this document, a matrix describing many of the different models and their general characteristics, individual/extensive model evaluations for at least 14 widely used models, and at least three unique model evaluation/use papers. All papers have been peer-reviewed by the committee. This document will also be maintained in a web-accessible format at the following URL: http://www3.bae.ncsu.edu/s273/

In the meantime, those interested can access the information available at the following URL: http://www3.bae.ncsu.edu/s273/ModelProj/index.html

Beginning in the fall of 2001, a new multi-state project will begin evaluating the Development and Assessment of TMDL Planning and Assessment Tools and Processes. The specific objectives of this project are to:

1. Develop, improve, and evaluate watershed models and other approaches for TMDL development and implementation.
2. Assess economic benefits and costs and equity issues (watershed and landowner scale).

3. Assess the potential ecological benefits/implications of TMDL implementation at watershed level.

We are currently preparing the proposal for this project. At this time, most of the participants are agricultural engineers or hydrologists from land grant universities or USDA-ARS. We are actively recruiting other disciplines and representatives of other universities and agencies to participate in the proposal writing and implementation of the project.

Panel 4: Measures of Models' Performance - Item B
David C. Goodrich, USDA-ARS, Southwest Watershed Research Center

It is my opinion that our modeling and computational capabilities have far outstripped our ability to collect sufficient distributed watershed observations (states and fluxes) to comprehensively assess them. At point and small scales, many physically-based models have been shown to perform relatively well. The real challenge in applying these models to larger basins is the characterization and treatment of variability and heterogeneity. The typical approach to this challenge is the use of spatially distributed hydrologic models. To properly validate distributed models, distributed observations of watershed states and fluxes are required. Without distributed observations a dimensional mismatch typically is present between the model parameter space which must be estimated and the dimension of the observational space [D (Para. Space) >> D (Obs. Space)] which is typically used to estimate model parameter through calibration. This dimensional mismatch often leads to parameter identification problems and non-uniqueness of calibrated parameters.

In some cases numerous observations of runoff through time can aid in the parameter calibration process. But is other instances runoff observations, our primary observations for hydrologic model calibration, are of very limited value. In an influent or "losing" environment where channel transmission losses are large (see Figure 1 – Tombstone, Arizona, and Figure 2) the observed runoff depth (runoff volume/drainage area) is often less than the measuring accuracy of rain gauges used to define the model input (large noise to signal ratio). In this case, and, I would argue, in most distributed model applications, we need other observations and other approaches (e.g. physical constraints) to adequately measure model performance. It is therefore critical that while advancing our hydrologic modeling capabilities we also advance our capabilities to obtain new distributed observations, data, and inexpensive reliable instruments for observation.

Figure 1: Mean Annual Runoff versus Drainage Area for three USDA-ARS Experimental Watersheds (Coshocton, Ohio; Reisel, Texas; and, Tombstone, Arizona)

Figure 2: Upper Portion: Total rainfall observed from the storm of 27 August 1982 interpolated from the dense rain gauge network of the USDA-ARS Walnut Gulch Experimental Watershed. Lower Portion: Observed runoff hydrographs from the same storm observed at flume 6, 2 and 1 (flume 6 is upstream of flume 2, which is upstream of flume 1).

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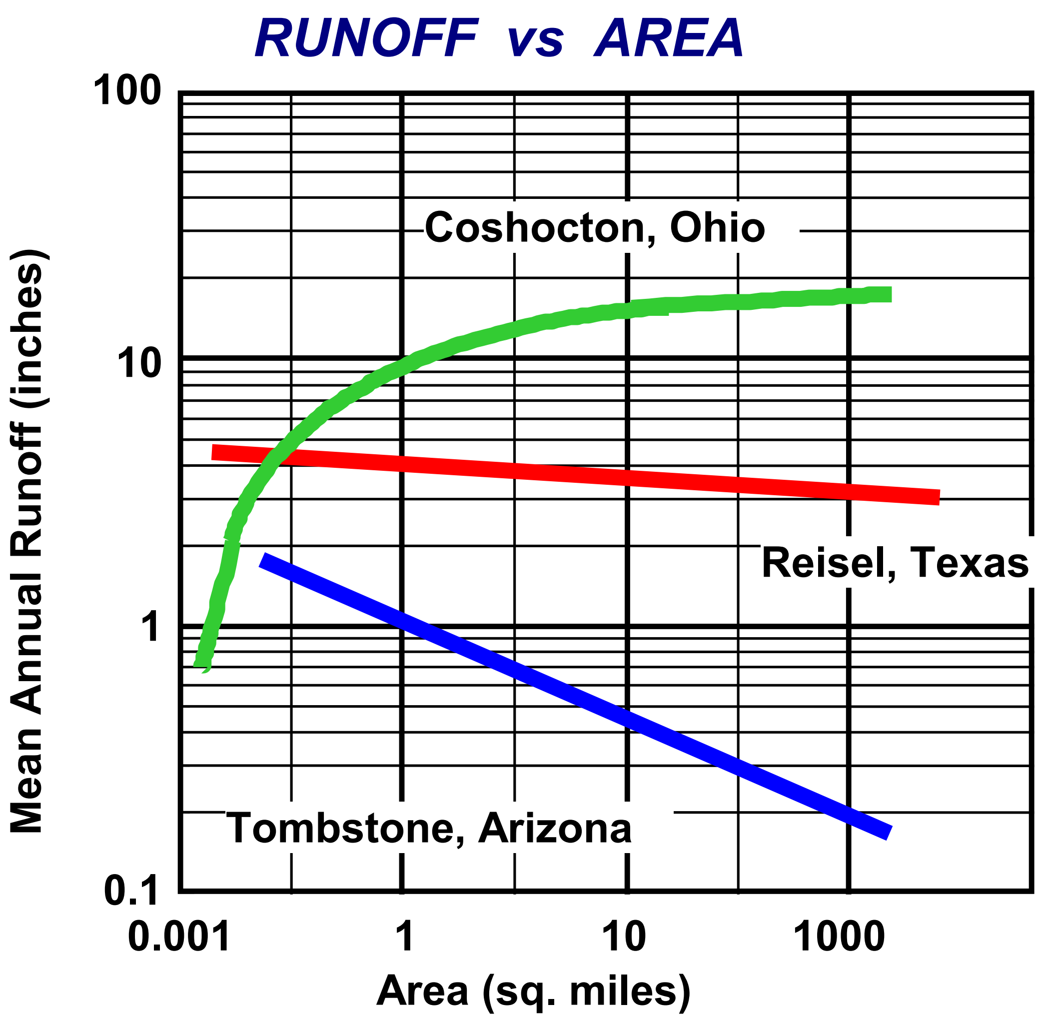

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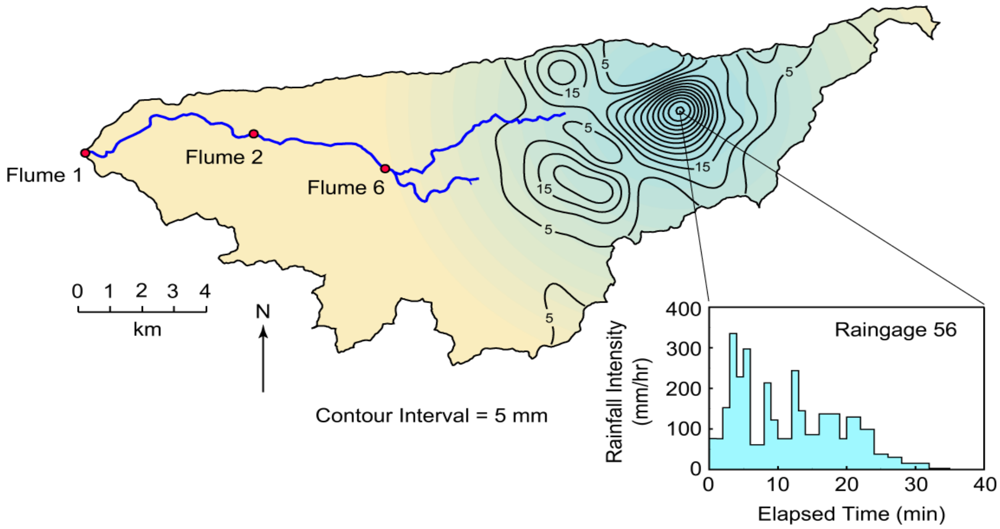

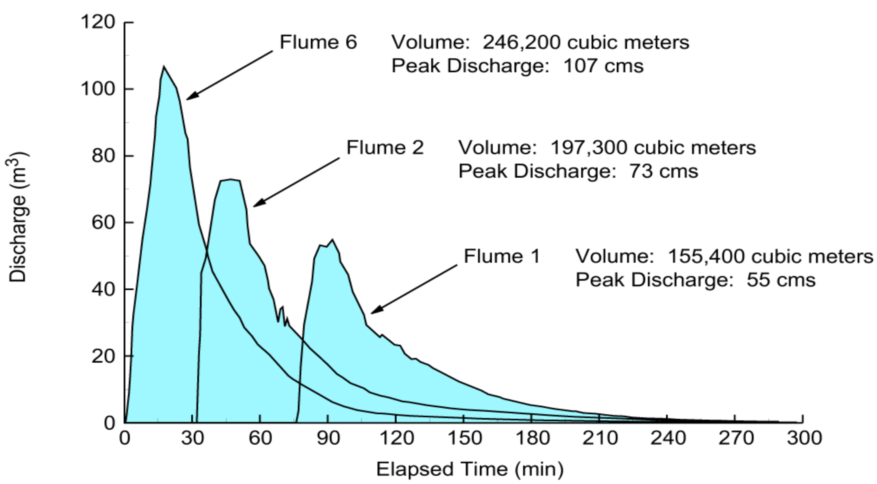

Panel 4: Measures of Models' Performance - Item C
Hydrosphere Resource Consultants, Inc
Benjamin L. Harding, Hydrosphere Resource Consultants, Inc.

Water Resources System Models

This presentation addresses the application and evaluation of models to the analysis of water resources systems. As used here, the term "water resources systems" means constructed systems for the storage or transpiration of water. The models used to analyze them are referred to as "water resources system models".

Water resources systems models have a number of characteristics that differentiate them from physical models. These characteristics are:

- **Applications** – System models are typically applied to system-wide analysis of policies. These policies concern both operations and configuration of the system. Operations issues can include the desire for increased efficiency, better flood protection or environmental mitigation. Configuration issues can include the need for new facilities or new water rights. While physical models are also used to evaluate the consequences of policy options, they are usually applied to parts of a system.
- **Access to structures and processes** – Constructed systems can be inspected and operating policies can be obtained. Historical system configurations and operating policies can be determined from documentation. Access to the structures, processes and parameters of physical systems are more restricted. For example, the hydrogeologic conditions in a groundwater system are usually known only from a sparse array of wells.
- **Consistency** – Though more accessible, the structures and processes of a water resources system vary among systems and within a given system vary over time. For example, the structures and rules on the Danube River are quite unlike those on the Pecos River. However, the physical rules governing hydraulic and hydrologic processes on the two rivers are identical.
- **Complexity/Diversity**—Water resources systems are typically less complex—they have fewer "moving parts"—than physical models. This means that water resources system models will have fewer parameters than physical models so their behavior will be more sensitive to any one parameter.

These characteristics give rise to a number of considerations in developing models of these systems. Some of these are:

Process representations cannot be generic—The variety of structural configurations and control processes used in water resources systems make it difficult to develop generic modeling codes—a code directly applicable to the Danube river would not be capable of representing operations or structures on the Pecos River. Control processes come in such a variety that considerable flexibility must be provided in their specification. Regardless of the method used to define these processes, one is “writing code” that can contain errors.

Process parameters change with time—In addition to varying across systems, process control parameters in a single system will change over time, at scales ranging from years to shifts. These changes can be intentional or unintentional, subtle or obvious, but they are almost always present.

Often no data for verification/calibration—Because system operating parameters vary with time, there may not be sufficiently long periods of homogeneous data necessary for calibration.

Validation & Verification

The subject of validation and verification of models is a contentious one. Researchers and model users cannot even agree on a terminology.

The dark view

The dark view of verification and validation, indeed of the utility of models, is put forward by Oreskes, et al. (1994). They argue on a philosophical level that models can be neither verified nor validated. Their political sensitivities are clear in the article (among others, suspicion of the science used to evaluate sites for long-term radioactive waste storage). Nevertheless, the paper, though potentially depressing to a modeler, is a good antidote to the naïve self-assurance that modelers can sometimes have, particularly if they have never gone into the field. Treating models as logical propositions, Oreskes, et al. argue that a model cannot be verified unless it represents a “closed” system, one in which all the rules are known. No natural system is closed, so no model of a natural system can be verified.

The realist’s view

The realist counters that Oreskes and her colleagues are essentially making a trivial argument: We can’t possibly establish that a model is telling the exact truth. “Of course”, the realist says, “but we can’t measure anything absolutely anyway. So should we stop measuring?” (Oreskes, et al. recognize that what we call measurements, except for counting, are really model results.) The conclusion that Oreskes et al. come to is that models are of little value because we can’t prove their truthfulness. But, Oreskes standard (logical perfection) is too strict. Useful models don’t need to be right. The realist cites one of the most common models that is universally recognized as being “wrong” but “useful”: a clock.

What good are models?

In the view of these writers, a model is like a novel:

> "…[It] may resonate with nature, but it is not a 'real' thing. Like a novel, a model may be convincing—it may 'ring true' if it is consistent with our experience of the natural world. But just as we may wonder how much the characters in a novel are drawn from real life, and how much is artifice, we might task the same of a model…"

Far from damning, if all models can do is be the scientific analogue of great literature, it's a lot. But, as modelers, we must strive to write well and precisely, to avoid cliches and, above all, dishonesty and bias.

In my view, perhaps the greatest value of the model is to the "writer" rather than the "reader", for the model forces a formal statement of a problem that has a way of bringing to the forefront questions that may be uncomfortable or unasked.

Evaluating System Models

At a practical level, what can we do to evaluate water resources models? The first thing, is to remember the old question that forms the philosophical basis for Total Quality Management systems: "Why is there never time to do it right, but always time to do it over?" One thing we at Hydrosphere have found helpful in "doing it right" is a good statement of requirements.

Based on hard-earned experience, we now propose formal development of a requirements statement for every model we build. This is best done in a separate phase, with its own funding. It is formalized and highly interactive and it must take some time (typically months) if it is to work as intended. On the surface it appears that the primary purpose is to educate us, the model developers, about the real system we will be simulating, but we also educate the system owners about the reality of models and, in a surprising number of cases, system owners learn some things about their own systems.

After the model is built, what can we do to make it "ring true"? For water resources systems models classical calibration is often impossible (for the practical as well as the philosophical reasons outlined above). We examine model performance at the atomic scale, which is a good way to gain confidence in the representation of discrete processes, but also at the global scale. By this I mean looking at mass fluxes and budgets aggregated over one dimension or another. A simple example is establishing that your model maintains mass balance. I've seen more than one widely-used model that created or destroyed water. Looking at these fluxes gives the modeler a way to compare at a high level the simulation they've created with the real system it is supposed to represent.

In making these evaluations, make good use of graphics and mapping. The ready availability of GIS software has added a powerful tool for evaluating model performance.

Make sensitivity analyses. Then ask yourself if the model behaves like the real system. You will learn something about your model and probably something about the real system. Focus your efforts on addressing uncertainty in the areas of the model that prove to have the most leverage on the results.

Get a peer review. This is not often done in the commercial world, though models used in litigation are brutally peer-reviewed. It should be a more common practice.

Finally, as a challenge to model code developers, we need methods to quantify the confidence we have in model results. With computer performance what it is today, built-in Monte Carlo analysis capability

Panel 4: Measures of Models' Performance - Item E
University of Arizona
Soroosh Sorooshian, SAHRA, UA

The research background of Dr. Sorooshian has been on the parameter estimation problem. Given a "real" watershed – the modeler is trying to minimize the distance (error) between the model's representation and the "true" system. How far a model is from the truth is dependent on the model structure and the parameters used to define that model (among other things). Automatic optimization methods (for finding parameter estimates) have progressed significantly; the global search algorithm SCE (Shuffled Complex Evolution) developed at the UA shows significant improvements over traditional optimization methods such as the Simplex. Long-standing biases against use of automatic techniques still exist; "single-step" automatic calibration has problems optimizing all aspects of hydrograph.

The UA has developed MACS (Multi-step Automatic Calibration Scheme) being implemented at several NWS RFCs to help in the calibration of watersheds used in flood forecasting. The MACS methodology has been able to reproduce manual calibration results. However, the future will be in multi-objective calibration – more complex models with multiple inputs/outputs. With multi-objective calibration, a "pareto" region is obtained which gives a number of valid parameter sets that have trade-offs. The range of predictions that results from the pareto set communicates some uncertainty in the model estimates. Multi-objective calibration methods can be used for both single-output models (streamflow forecasting), and the more complex multiple-output land-surface models.

A key issue in these modeling efforts is the input data, especially precipitation. In the SW, precipitation estimates are poor due to mountain blockage of the radar signal, poor Z-R relationships, and sparse rain-gauge networks. Satellite estimates are the future – especially in semi-arid regions like the SW. The hydrologic community needs to be more supportive in efforts to get improved NEXRAD and satellite precipitation estimates. Upcoming NASA missions have precipitation listed as a highest priority – hydrologists have a responsibility to get involved and be aggressive on demands for better quality precipitation products. The hydrologic community also needs to become more involved in national/international programs such as GEWEX/GCIP and GEWEX/GAPP. Their voice has been absent in giving input to these types of research programs.

BREAKOUT SESSION & DISCUSSION - PANEL 1
SOFTWARE DEVELOPMENT PHILOSOPHY AND ENVIRONMENT

Introduction-
Panel of hydrologic Modelers and software developers. Nature and role of software itself plays a role in hydrologic science. Panel will address current issues and recommend future directions. Start with their work and then open it up to the floor.

George Leavesley, USGS

Modular Modeling System, **MMS**
- there is no universal model
- models differ by details, objectives, data and scale

Pre-process => Modeling => Post-process
Types of modeling process:
  loosely coupled; 1-way
  fully coupled; 2-way
  resource management
  analysis and support tools
- should relate to real-world components
- input ⇔ output

MMS acts as an interface for all the individual model processes.
- Starting points- The level of complexity in a model depends on its application.
- A structure is a toolbox. Core of model with various modules (e.g. optimization).

Modular design: You can link precip model A with evap model B… Assemble model to fit the problem. A number of people have written about modular models. (He's reading directly from the slides at this point).
Model structure can be built on the fly…
User interface built for users.
Coupled models - e.g. coupled groundwater/surface water model. Design mechanisms need to be in place to handle strongly coupled models.
Loosely coupled models- "forcing models"… e.g. watershed model forces a fish model with no feedback. The structure of the model does not to be as tightly coupled in this case.

Example: Gunnison River Basin Colorado. Java Based tool set to build model linkages. Written in XML.

Decision support systems: example, BOR and USGS linking RIVERWARE system (river and reservoir management system developed at U Colorado) with Data Management system, MMS.
Other examples: WARSMP basin studies.

Analysis and support tools: currently, there is the GIS weasel, Rosenbrock Optimization, Troutman sensitivity analysis and a forecast model, being added are other optimization techniques such as Shuffle Complex Evolution SCE, and Multi-Obj. COMplex Evolution MOCOM.

Focus on GIS weasel… you can have many different frames of reference (grided, watershed based, elevation based). Can use GIS weasel to automatically determine parameters.

Work is going on with Los Alamos to parallelize MMS for high performance computing.

MMS Collaborators (see slide list). Designed to satisfy research and operations needs. Agencies, academics…
BOR; BLM; USDA; DOE; Germany, Japan

Some of the Disadvantages of MMS:
- acceptance of modular system
- willingness to share code and data
- loss of model name recognition

Advantages:
- community toolbox
- flexibility

Summarize- The philosophy of modeling and science are different. Science – incremental improvement… in contrast, many different models without much room for improvement. MMS gives a more science based approach to modeling. Everyone tends to build their own models
Need to Ask Why? To move forward

Costs/Benefits – (reading off the slide).
Website: http://wwwbrr.cr.usgs.gov/mms/

Darryl Davis, HEC, Army Corps of Engineers
Next – Generation Software

Corps is a large agency… His subagency (HEC) is small. He does training and development and applied research, software development to support nationwide offices. 30 years of experience in developing USACOE software. Hydrologic Engineering Center Design – designed for a specific user community. Design, build and field models for users and users only. Corp field offices have responsibilities for planning, design, realtime project operations, regulations, permitting and regulatory. Try to have an open process in developing new techniques, lots of discussion… make it available for testing for people on an international basis. Several 100 field testers to provide feedback… many outside the US. NEXTGEN new project to take a fresh look at modeling for engineers and they decided not to incrementally improve models but instead replace them. HEC-RES SIM, HEC FDA, etc.
Days of the one model, one person, and one program are all long gone. Nowadays, teams are used in developing models with the additional input from other consultants who are involved in model coding and building. Although someone serves as a leader, the model is truly developed by a team or people.

Integration – need complete water resources analysis. 4 groups of models – hydrology, fluvial, reservoir and impact components. Worked to have common schematic, data exchange formats, etc to make sure all models are compatible. Corps water management software project. Decision support and forecast models put into other models so they can be run in automatic/scheduled mode. HEC DSS… Want to develop an entire package ready for delivery to field office.

GUIS and Multi-platforms – 6 month projects are now 3 years b/c of GUIS. More than ½ of developmental effort. Can bump up budgets an order of magnitude. Want to make their models multi-platform. Only HEC- RES no multi-platform (visual basic) because they were under deadline pressures. Galaxy – proprietary GUI… now replaced by JAVA. Will soon replace GUIs and graphics features with JAVA code to make them platform independent. Are now going back to do old software in the same way. SWIMMS- corps water management project client server system. Control and visualization interface can run on Solaris and PC.

Object oriented – we are committed to developing in this manner… Have some successes but not all. "The Emperor" does have clothes and object oriented approach is valuable and institutional process. Software of choice JAVA… Don't use it for web; use it for object oriented features. Helps with international applications (metric/English, universal time code). It has not been easy in the culture of Fortran; not an easy transition. Software has Java, C, C++, and Fortran.

Proprietary verus public domain- All software in public domain, developed at public expense. Intellectual stock (not where the funding comes from)… e.g. if a contractor develops something, they may copyright.

GIS verus model centric – they are in the model centric camp. GIS is information to improve models. Built things to extract info from GIS. HEC-GEORAS, GEOHMS.

Shorthand of above
- designs are specifically for field engineers of the US Army
- design, regulation, application, implementation
- open process, worldwide, open-minded
- testing
- not just to improve but replace with new products e.g. HEC-FDA
- every product is a team-effort
- no study is a single study; but an integrated, complete process

4 groups: hydro, fluvial, reservoir, and impact assessment
common features among products: same schematics, naming, data exchange format; made possible by a core water data management system and automation.
-knowledge that nowadays you have to have Graphical User Interphase GUI even though it may increase development time from 6 months to 3 yrs, and might make up half of he software development efforts.

HEC-RAS – single platform; there is always a need to be multi-platform because of the grant nature of the Agency; different people using different machines.

HEC-FDA - flood control, part of the code is proprietary, use a lot of the old galaxy GUI, which become dead when platform-independent Java came out.

- Integration system – SWIM, client-server system i.e. no more multiple installation but a single installation to the server and the clients are simply for graphics and outputs.
Only object-oriented structure of Java is adopted into HEC, and not for its web capability.
All its software tries to be universal e.g. using UTM times and universal units
- speaker comments the difficulty to move from Fortran to Java, and compare it to a culture change. It still deals with multi-code challenges

Proprietary vs. public
- he said all products are viewed as public.
last remark: GIS and geography are viewed as supplementary data that better the models themselves e.g. HEC GEORAS and GEOHMS
http://www.hec.usace.army.mil/software/.

Henrik Sorenson (based in Montgomery, AL)
DHI – Danish Hydrologic Institute

- coupling and integration of codes
Independent self governing research and consultant organization. Build competence and promote technological development relevant to the water and the environment. World-wide activities. Staff of around 500, approximately 100 staff member work within R&D.
-independent from Danish government, profit-oriented, non-taxable
Main US office Philadelphia, PA

- EU only have 3 to 4 major software developers i.e. resources concentrated in the hands of few
- trademark products: Mike SWIM, Mike EPAnet, Mike SHE, and the mike series
- he went to demonstrate some examples from the Mike series

Models for water quality, water sediments,
MOUSE model – sewer model**, MIKE SWMM, MIKE INFO, MIKE21, MIKE BASIN, MIKE-SHE, MIKE 11, MIKE3** models
MIKE-11 – 1-d flood depth analysis
MIKE-SHE – integrated gw / sw model
Mike Basin – Water management/ water use model
Mike 21 – 2 D Model from navier stokes equation. Use for making tide/wave forecasts… Can forecast small scale waves to model erosion.
Mike 21C – morphology… Bridge scour.
Mike 3 – 3D Navier stokes model. Useful in environmental impacts assessment. Salinity tracers between Denmark and Sweden.
Had very Good result visualization; seeing is believing.

DHI tomorrow – Integrated solutions that requiring coupling. E.g. coupling MOUSE and Mike11. Build the model for the application by linking models. Full flexibility for combining models e.g.1D channel to 2D floodplains or coupling among the MIKES. Open code architecture to enhance interfacing. Keeping it open for people to develop home made codes or adopting public codes
Application-oriented packages; try to provide a suite of tools that solve the whole-picture e.g. MIKE-Urban, the Ultimate surface water model – a gaggle of Mike models linked, interacting, coupled. Aren't there yet, but can do quite a bit so far.
He agrees that it's not the model, it's the modeler… The human element is important for creativity, but also misuse!
Would like flexibility to shift between 1, 2 and 3 D approaches and combine them.
MIKE SHE – integrated hydrologic modeling system, which has been available since 1996. Various Mike models linked together with feedbacks. See slide for details. Plan to include modflow in 1 – 2 years. Addons for water quality.

Major modeling effort in Florida.

GUI Structure. General trends towards

Russell Kinerson,
Office of Water, Office of Science and Technology, US EPA

Talks mainly about **BASINS** – better assessment of point and non-point sources
Why Basins?
Permit Writers' job: C = W/Q
If C > C required, reduce W
It all about dilution in time and space
21000 water bodies, 41000 impoundments

Motivation for development – Writing permits depends on whether emissions exceed loads. TMDLs – controversial… Not everything is a point source.
On non-point sources, it depends on weather, harder to manage (can't turn off a valve).
Skipped hydrologic cycle.

Permit writers did not have a good understanding of the hydrologic cycle and didn't have a good basis for blending point source and non-point source. Most people have desktop computers with Arc View… Not Unix. BASINS ver. 1.0 out in 1996 with HRU scale; proof of concept, backbone – GIS ArcView PC, extremely limited. BASINS ver 2.0 allowed dynamic simulation. BASINS version. 3.0 due out soon. Currently beta testing BASINS 3.0.

HSPF… previously the only such model available. Now there are several choices. New model has a complete windows interface. Similarity in interface not because it's the best, but that's what people are used to.

- software to integrate point and non-point sources

point-source discharges – steady
non-point sources – dynamic

Watershed models
- screening – PLOAD
- midrange – GWLF Generalized Watershed Loading Functions
- detailed – SWAT (Soil and Water Assessment Tools), HSPF (hydro simulation program) WINHSPF – window interface

GENScn/WDMUtil – allows user to develop time series. – post processor; interface for scenario development and analysis
Expanding features – modular system, installs the whole system in modular extensions forms, standardized output
Spent 400000/yr on training for BASINS in the beginning
Website: www.epa.gov/ost/basins/

Challenge – combining different models/platforms. Chose ArcView on PCs because that's the major tool for permit writers. Also chose visualbasic6. Question: will 3.0 information be available on the web? Currently it's 2.0? 3.0 will appear on the web page. Talk rushed and didn't match well with visuals.

David Maidment, UTAustin

Spatial hydrological modeling
Input ⇔ data ⇔ models ⇔ results
Traditional modeling – GIS linked with Models "coupled but decoupled".
National Hydro Data Programs. 4 programs in development.
Two major data sources are from NED and NHD
NED – Seamless elevation dataset over the country. Very high quality
NED – Hydrologic derivatives 8km2 basins ~ about the size of a nexrad cell for flood warning.
Watershed boundary dataset – NED H – 16 digit level.
National hydrography dataset – HUC units with river network data, water bodies.
Standards of National River addressing system (allows you to pinpoint location, by basin, segment, etc). Previously universal hydrologic referencing system not available but now in development.
All in all, 10 billion data points and 30 meter resolution, 5000 threshold DLG – streamlines
New reach code: HUC# followed by Segment#
Made possible by polyline M
GIS in Water Resource Consortium
ArcGIS Hydro Data Model – 4 components:
water/catchment boundary
hydrological features
river/channel network, cross-sections
time series
ESRI provides Vanilla objects for encapsulation

2 objects – one for carry info and the other for query info
Cross-sections info developed by Jim Nelson, BYU with polyline
UML diagram

GIS and Water resource consortium – linking Gis and water resources. Devise a data-model

Core of model was a river network model… catchments to deal with 3 d aspects…. Time series then linked with maps. Vanilla objects…???
UML??? Technical discussion of GIS.

CDROM – public domain model, open for review…
Talking about individual components…

Edges and junctions
Flow edges and virtual flow edges going through water bodies and shorelines
Can deal with flow to shorelines by shore catchments
New advancement to talk not only about flow through river, but flow directly to water bodies.
Allows you to go to a point and then highlight all upstream areas.
River channels in 3 dimensions.
Not just a spatial database, but time series as well (linking with USGS water information system).

Future directions: Hydro-objects: linking several different models.

Websites available and training available… Book and CD with model.

GeoDatabase Book Series due out.
Public domain framework
Everyone competing for the same goal
GIS meeting in Austin in December
Website: http://www.crwr.utexas.edu/giswr
Panel Discussion.

Question 1. Coupling of existing models… if it was one way, then it's just a matter of languages… But if it's two ways, how do you make two way models interact? A: There are two methods… Solving internally and interacting? Hard to hear question (directed to mike she person).

Question 2. How do you balance between model development and training requirements? EPA: Don't have a good answer but that's a good question. Lots of training is necessary, sometimes they do cost sharing of education, which has been found to be helpful. Corps: Develop software to make life easier to users… Therefore innovation is good… but software development $ has been on the decline. They try to minimize training required by making the software as user friendly as possible. Leavesley – "drawing the line correctly". Linux philosophy… Have a guiding philosophy but the entire community contributes. Mike She: Modular system allows you to build up incrementally, helping people understand the small stuff and then develop more complex things.

Question 3. Interfacing models and standards. Time series and spatial data transfer uniformity. Interested in hearing from federal agencies about standardizing. Corps: Data exchange in real-time is CHEF… That's fairly uniform and standard. But it would be a good idea to develop a subgroup for developing that. Needed to have a standardized format within there software and they developed it, so it's possible. USGS – agree that standardization is important. There are as many databases as there are modelers. Maidment – this summer about 2 months of debate with ESRI. He outlined his method via PowerPoint. 4 D tags (space, time, value). Developed systems to integrate spatial data and time series data.

Question 4. How do you look at the propagation of errors within models/between models? When data is eventually passed on to decision model, the decision can bear no resemblance to reality. It's not so much the ease of use of the model that's important as much as understanding the underlying physics/model. USGS A fool with a tool is still a tool. It's important for people to be smart about the models… We're working with UofA and GLUE to adjust for uncertainties in the models. ACOE- provided example of where propagation of errors in real life situation. Community should have been experiencing damages every other year, but they didn't have floods in 50 years. Each component firm that their component was good… But if someone had a "big picture" and everyone was responsible at all steps, then it would've been a better process.

Question 5 (Bisher Imam). Point based model and data verus grid based models… coupling with atmospheric models. Maidment – it's a long battle to get people to used referenced point data… Move slowly towards grids. Locations of points change, e.g. under flood conditions, shifting channels, but this is something to develops towards… slowly. ACOE. Flood forecasting component always operates in a grided format…. This links well with nexrad data. Their system embraces spatially data.

Question 6 (Soroosh). Not only uncertainty in data but also uncertainty in model as well… How happy are you with the transfer of knowledge from climate models/SVATS to hydrologic models? USGS- advances have been relatively slow. Hydrology always limited by spatial factor… therefore always use simplified equations. When atmospheric sciences came along, there was an opportunity to get fully spatially developed… We're making mechanical links to ingest this information; we're working with these communities, with mixed success. Atmospheric models drizzle, they don't rain. Snowy regions are very good, but rainfall runoff areas do very poorly because of precip intensity issues. Mike She – at minimum, the models should include packages of calibration, validation to get the best model possible. Maidment – Have linked model with NCAR Climate model. 150,000 parameterized units, linking with grid cells. Source to sink routing is a modeling innovation.

Question 7. How do you link models between agencies… physics and data formats? Can you? ACOE – the easy answer is yes, if the models are not coupled. We already do that with snowmelt. Leavesely - You would have to turn the other models into modules and then you can link it. We've developed some components.

Question 8 (Norman Crawford)- Microsoft's budget is infinitely greater than the hydrologic community, so we're kind of at their mercy, but we can also use this to our advantage… Look into XML as a method for exchanging data between programs (allows data to describe itself). Leavesley – yes, our next generation is all centered around XML. We also have a data dictionary (so there's standardized definitions of "surface roughness", etc).

Question 9 Hoshin Gupta – Literacy and the issues of training. Standards of concepts for students. How do you keep students from being trapped in domain knowledge (e.g. only knowing Sacramento model)? Maidment – has a website, does teaching course via streaming video, remote teaching is all archived. Internet has a great potential for teaching. Leavesley – MMS is all about open systems but with standardized documentation (input, output, text description). This prevents people from being limited. They provide tutorials on the web, so people can go at their own pace. Need to think outside the box in an open framework. EPA – Basins has taught us that many of our users are (international) graduate students. GUIs and GIS have made it much easier for users to apply different models. The ability to work with more than one model helps people think better, be more adaptable. ACOE – try to be good about making reference materials available. But you shouldn't be teaching software, you should be teaching concepts. Learning a software package is a small component of engineering education.

Shorthand version of above questions
How to couple 2 stand-alone models?
Henrik: by 2-way feedbacks

Does it worth to constantly models? How the users take it?
- benefits of reinventing the circles
- depends on who draws the circle correctly; it's like betting who's going to get it right!
- have to work with students and university and training, work together, self-help
Bisher: Is there an effort for a time-series transfer standard
Maidment: Yes, spatial data series developed with ERSI: ARC GIS
Audience: government standard: GRASS GIS
Davis: HEC-TSS, passing of time-series data, ability to use NEXRAD grided data
Maidment: grid ⇔ point; time-dependent shapefiles and time-sequencing grid are examples of time-varying spatial structures

How to account for propagation error?
Is it good to couple or not? Increasing error?
Basically need to account for error and uncertainty for results to have meaning. And bear in mind that there is a range of optimal solution.

Are there any thoughts about model structure itself?
It is slow in advancing. Basically start with simple models, when integrating different models, it becomes very complex. There are also problems with scales. Different models have different scales.

How to integrate between different camps? (e.g. MIKESHE and HECRAS)

MMS provides a good interface to facilitate that. XML as a method to exchange data. XML makes it possible for data to describe itself before exchanging is possible. MMS also has a data-dictionary for agreed-upon naming methodology

Education is the key. Major users of models are graduated students. Need to expand education base. Maidment gave an example about his streaming video lecture coordinated the BYU. Education needs to be easy, fun and useful experience. Who read the documentation really? Documentation needs to be simple and fun so people will actually read them. Students need to know multiple models, and have a broad basic knowledge.

Panel 1 - Model Development breakout group:

Purpose of breakout group: needs and problems brought up in this session and other sessions but relate to this topic.
All topics include the topics addressed by panel members and other relevant.

Question: when are we done? Follow-up – our purpose is to help develop the agenda of the future meeting.
Critical Issues:

System architecture – Model centric versus GIS versus data centric models. Open code architecture.

"You're either in one camp or the other"- AcoE. There are more productive things to argue about. Open code architecture – open to putting code in public domain code, but not getting out. Worthwhile topic (open code architecture, model centric v GIS v datacentric)

Platform and software choices – should all software be multiplatform? If not, then what platform? How do we make the best choices? Programming languages and criteria for choosing? Inclusion of Fortran legacy code or should it be entirely rewritten?

JAVA seems to be language of choice. It's not the last language ever. Occasionally Acoe reverts to C because it's necessary. New Java is much better at computational performance than the past.
What message do we send to students about what code to learn – Generally that's determined on the job. How do stay current/ahead of the curve? It's good to have these projects as team projects rather than individuals. It's not wise to encourage "individual" builder of code. Does the agency even have an influence on the curriculum? If students learn JAVA right away… what about Fortran? Is that really an issue- often times software is self taught. Once you learn one language, then you can learn about any of them.

New generation of civil engineers v old generation. Old – all engineers learnt Fortran b/c it was the common language. New – CS students know JAVA, but engineers are exposed a little to Fortran, C but mostly spreadsheet, Matlab.

ACOE – hires a suite of people to fill all the tasks at hand… Nobody does everything. Almost prefer engineers w/o java background, because it shows they've focused on their core research.

Model coupling – surface gw coupling, atmo-LSM coupling, hydrologic economic coupling etc. Coupling within a system… Coupling outside of a system (Loose versus strong coupling). Issues of common data formats (see data formats later).

Question is not internal coupling, but coupling between models (eg. MMS and something else). Should there be a standardized method for coupling models? Coupling to let you pass data in standardized formats… Another kind has to deal with network topology. Spatial consideration key – radar grids, polygons, node points, impact analysis areas, transects, etc. MMS weasel does that automatically.
Is this discussion still about sharing data? This is just about sequential models… What about feedbacks and truly coupled models, process coupling? To date, developers have avoided this, but it's becoming a growing issue. Occasionally get numerical instability, solutions do not converge, etc. Are these issues getting addressed? Technical discussion about modeling coupling follows… Interdependent coupling.

Would it be useful/appropriate to standardize data formats to facilitate transfer between models? Would it even be possible? XML?
GUI Development – Explosion of costs associated with GUI development. How much pretty is too much and not useful? What is the real objective? Do you want it to be too easy to use? Would you rather work on the engine or the body?
Scripting… Didn't come out yesterday. Ability of the user to create home made procedures within a program. Riverware does this explicitly b/c it accounts for complexity that "standard" models can't capture. (Darryl Davis: scripting is also scheduling of model… e.g. setting it to run overnight. Similar to DMI in Riverware. User can customize displays, output configuration. "Active live system" – internal messaging system that monitors internal components functioning (e.g. model crashes, sends email to user). Another audience comment: what's your code. Response: Java and J Python. Leavesley – we're also doing something similar to XML with MMS. Do you find that this is necessary? Or a byproduct of moving towards Java? Response: we've always known that that's needed, but now we have capability. There are a variety of scripting languages just as there are variety of modeling languages. Russell Kinerson: GIS has something similar [scriptings], and it's very powerful. Scripting is useful in many contexts.

How do the little guys keep up? Response: there are many freeware applications that can be used. J Python is the top of the line, so you need to find out where you fit in along that continuum.
GUI the corps is building is adaptable to use on any model, customizable with scripts. Can be applied to economic model, hydrologic model, etc. Would like to see a session on

scripts because it's a hot topic. User customizable and User Directed. Scripter in riverware is different – it's deals with intelligent operations.

Discussion of Grass…

Multi-platform discussion very important because Microsoft as being invincible has become dogma. All new corps code is in Java. Lots of old code in Fortran that they haven't thrown away.
Fortran code is designed for computations. The other codes are more optimized for graphics, not computation… Response: maybe 10 years ago that would make a difference, but now hardware is cheap. Response to response – 3 D groundwater models running very slow on pc. Rebuttal: multiplatform is necessary. 2nd Rebuttal – maybe a hybrid system would be best, with Fortran core and C++/JAVA graphics. 3rd Rebuttal – Read my lips – no new Fortran code. Everything *new* is in Java. Leavesley – put a java wrapper around your code.

We're approaching gigahertz processer speed… Does writing in Java mesh well with parallelization? Answer: sure!
Leavesley – we're going to have to go to a baewulf cluster if we're using SCE and GLUE with all its Monte-Carlo use.

GUI programs… Do we have capability to run GUIs in batch model? Response – that's what scripts are for! Rebuttal – does this require education on the part of users? 2nd rebuttal – the user should care less about the language and the guts of the problem and focus more on bringing information to the program and getting results. Maybe shouldn't even care about platform. 3rd rebuttal – provided example of running HEC in batch mode. Wrote a pre processor, post processors etc. Can I do that with HEC HMS? What computing skill would we need? 4th – If you're a research, we're not inclined to make your life easier… Our focus is on the field offices. Should the field office need to do Monte- Carlo, then maybe we'll build that in. 5th – we don't have capability of embedding the code in something else 6th – the GUI and engine are separate. You can always pick out the engine and work on that separately… That's standard practice.

Question- should users be concerned with language/platform? If so, how do we go about doing that?
Response – I'd suggest using Java and is supportive of Corp viewpoint. However, EPA chose not to use JAVA development because there was a short term solution that was needed. Ended up with PC platform with windows environment, arc view, extensions in avenue script, soon to be vb6, vb7. That's a result of an agreement between ESRI and Microsoft. Corps has agreement with ESRI… ESRI is moving towards VB. But someone else said that ESRI is now moving towards Java (because of outcry from Linux community). (Wow!) Getting that info out of ESRI is hard… No timeframe available. Corps will find out within the next month. There was a hydrologic session at the summer ESRI conference, surprising to see such a focus on hydrology.

Issues of data streaming. Acquiring data. Is building systems about acquiring information from the internet such a good thing? Corps ingests hundreds of thousands of information bits in real time and deals with that issue. How complex a data structure are we

committed to stream? How much should be stored locally and how much should be available remotely? If data disappears, then what? EPA looks for convenience, but is this a good idea? In an emergency, you can always go by CDROM. The real challenge is drawing this all together on the fly. Corporate entity of GIS, multiple users. Segue from Corps – client server is the base for corps. Reliability and bandwith and performance have become issues… 10 years ago, hard to imagine that these would be problems today. What to do? Individual computer? Server within an office? Regional high power server? It's become a critical issue: server location, bandwith, networks. Programs are now working on the server, with GUIs on the users computers (except Corps view, which works by xview). It's not a terminal… It's a client, a "smart" terminal.
Corps architecture: Sun workstations that are the servers for oracle database, model computations. In offices around headquarters or field, there are high speeds LANs to servers and they have complete client software. They allow all the setup of the models, execution, posting of the results back to the (???). Users exchange information with each other via conventional web technology. Discussion of certificates and r hosts. Server side is a more robust platform.

How does the little guy break into all of this to help development? (not sure about what the answer was)
All of these topics go back to "who are you building this for?" Field offices, research, regulation, realtime, etc.

Issues of security- esp. for military applications. Going over the web can be dangerous. SWMMS is security protected at all levels of access. But this is an house issue.

Standardized data formats – should it be a goal, is it possible? Could some day all hydrologic models all talk to each other? What kinds of software are conducive to this? Not entirely convinced that this is possible. Different kinds of data required for different kinds of models. XML contains information about the data. XXL. Is this something that the hydrologic community should be interested? Answer: hydrologic models are time series items. EPA: were developing a utility to allow users to develop additional meteorological datasets. NETCDF changed several times so the data was no longer readable. Maybe have a central committee on data standardization providing translators? ACOE spent months and months developing a standard time stamp, including universal time. Not an easy task. Might be able to do it for individual things, like flow data, but if you do that to everything (flow, bird counts, phase of the moon) fugghedaboutit.
Hard items: peculiarities in real world… Non continuous variables, quality flags. There might be a subset of data to start with. But when you get different companies, e.g. ESRI, GIS, how do you translate all those things into standardized format? Sometimes for convenience, you have to accept a temporary solution that may not be standardized. Agencies can (relatively) easily internally standardize, but once you interface with the public, it gets significantly more complicated. We're in the early business of standardization. USACE – not necessarily negative to duplicate effort… work until there's enough maturity to mesh.
Need some equivalent to SI units for formatting, able to translate back and forth.
Talk about origins and pathways in environments (?) SQL query structures.
Good to include a

Public vs Private domain, avoiding redundancy in model development, controlling costs of model development. User support (kind of sort of not really). Won't hurt to list it as a topic at the conference, but not necessary to discuss it in depth here. Issues of sharing GUIs. If GUIs consistent, then users can catch on much quicker.

Post discussion: integration of GIS technology in hydrologic modeling session proposed. Data models and methodologies. Includes parameter estimation, visualization, etc.
Do we have continuous or parallel sessions?

General group discussion-
Student computer literacy – System skills vs computer skills. Not just learning about Java but learning about model structure as well.
It would be useful to establish a mechanism for feedback to educational institutions from the field about directions and requirements in the field (with respect to computer languages, software etc).

With respect to data/model standardization… Modest extensions are a good start. NGDC (?) system to accommodate time series data (similar to Maidment)
What about adopting GIS standards? What about existing model standards (e.g. MMS?)
Do standards have to be international? What body would take care of this – WMO?
Much discussion has been about time series data… What's the spatial data standard?
Someone joked that ESRI is determining standard. Questions about "Do we want to be held hostage to ESRI? We want to *set* standards vs *adopting* them based on the needs of the hydrology community.

BREAKOUT SESSION & DISCUSSION - PANEL 2
Roles of State/Federal/University/Private Organizations

The comments from the panelists centered around four questions (paraphrased):

1. What, if anything is wrong, with the status quo?
2. If the status-quo is non-optimal what is best role for each sector?
3. What obligation does your sector have to share information with other sectors?
4. What opportunities do you see for cooperation and sharing with other sectors?

The panelists generally responded directly to each question.

Jim Nelson - University (BYU)

Background--EMRL develops software and sells it on the private market through distributors. Started with scientific visualization. The combined with Army Corps of Engineers to specialize in water resources (SMS, WMS, GMS). Now do data transform for input information (GUI). ERDC have distribution rights, EMRL used to license software then moved this to a private company. Resources of EMRL from existing libraries, FHWA, ERDC sponsorship, and commercial sales. Advantage to agency: state of art visualization, better final product, maintenance and support, emerging technologies tested. Advantage to EMRL - constant source of funding. Advantage to private - not all development costs borne.

Is there a status quo?
Description of sector above
Open data sharing described above
Meetings like this to see different perspectives

Mike Smith - NWS (research and development for river forecasts, promoting inter-comparison of distributed models).

Duplication of effort - not sure how to move ahead with distributed modeling, limited ability to provide support, model presently used in NWS is hard to change and adapt
- federal government facilitate coordination and communication and promote collaboration
- federal government has no obligation to share software, also their (federal) software can't be copywritten
- more workshops, 2002 conference, special sessions, support seminars.

Tony Donigan - PRIVATE DEVELOPER (not proprietary software, funding from various sources).

- Federal agency is the driving force to develop models for specific needs concerning the missions of the agency, little state involvement, both private and university develop under - federal funding. Dont expect rapid or radical change.

- Eg. HSPF - funded under EPA 20 years ago, since then added to capabilities using wide range of funding new model always builds on latest version. Facilitate cooperation between agencies and advance for all.
- Public funding = public domain, not entirely true.

- Need a Federal or university modeling center to stabilize funding for major models.
- Need a guide on how to select models.
- intercomparisons of models
- define standards for calibration and validation.
- sources of maintenance support and training (private??)

Sasa Tomic, **Haested Methods** - SOFTWARE DISTRIBUTOR

- Haested methods (background to company on overheads).
- not much wrong - more information sharing, no common platform, no standards
- developer/distributor should provide end user solutions
- need to promote sharing of information to help users and get feedback
- get data from web in any format and convert to usefulness.
- use trendy interfaces between data and models.

Sushil Aurora - CA, State agency (large scale planning policy making models).

- Software tends to be proprietary, lack of training and documentation, models not consistent between agencies, no modeling protocols to adhere to.
- University/public development, means widely available, use Internet, peer review process helps gain acceptance.
- When making policy studies have obligation to share models, data, and algorithms.
- Cooperation benefits, more qualified staff.

Questions to Panelists:

Is a snazzy front end detrimental to science? - need to use visualization in an educated manner.

How do we ensure model is used by someone wise? - education and training make cumbersome inclusions so need to know something to use it.

How to go by philosophy of using range of parameter sets to get range of solutions? - Cant make users do this, need some guidance mechanism on how to effectively use the model. Need someone to trust and train to operate model. U of AZ multi criteria procedures one way of using philosophy. Engineers often do risk analyses to get a pdf of expected results.

Is the use of a 'black box' model valuable? Not any time soon, with any confidence in the results.

Any protection / support for software with vendors going out of business?
What happens to software if developer leaves? - build in maintenance for usability of code, more than one person works on software.

Breakout Session: Following is a list of summary points that emerged as consensus responses to the four questions posed to Panel 2.

Q1: There is a need to remain open minded about solutions and open to possibilities of knowledge sharing.

Strongly suggested to establish and possible require algorithm standards/regulations.
Benchmarks should be a key aspect in adoption and approval of new algorithms.
The community could substantially benefit from better coordination of research efforts to avoid extraneous duplication of efforts. Institutionalization of model development, through a steering committee or the like, may provide a forum to address these issues and guide future research.

Q2: Consensus is that the federal government has been and will continue to be responsible for the bulk of the model development. However, opportunities exist for the private sector and Universities to educate and provide support in the use of hydrologic/hydraulic models.

Reiteration of the desire to have a procedure for government/institutional testing and approval of software.

Q3: The obligation to share information is still being defined. It was suggested that a public education effort may need to be mounted in order to explain why some federally developed models are licensed and to explain the benefits derived from licensing.

Federal government may also have a role in the intercomparison of models and regulation of algorithms. It was noted that NWS is already embarking on such an initiative.

Q4: Opportunities discussed included exchanging scientific information and the sharing/distribution of validation datasets.

Future Workshop Session Suggestions:
Large scale system modeling
Educational requirements for hydrological modeling

BREAKOUT SESSION & DISCUSSION - PANEL 3
APPROPRIATE USE AND GUIDANCE FOR MODELS

Moderator: Don Woodward, NRCS

Appropriate uses of models
A model is easy to use, easy to abuse
a. South Florida Water Management District, Obey Obeysekera

Many modelers here have worked in South Florida. It is characterized by flat topography and high water table. All kinds of models have been used.

A model is like a novel…

Common modeling mistakes and potential mistakes are in four categories:

1. Improper conceptualization
2. Selection of inappropriate code
3. Improper model application
4. ?

* Conceptualization of the hydrologic systems:
Misunderstanding of model objective which is the biggest mistake
Omissions
Improper degree?

Potential Solution:
Publication of standard practice (ASTM American Society Testing and Materials)
Intercomparison of models.
More training programs.

* Not picking up the right model to simulate the system
Selection of code that has not been verified or tested for application

Potential solution:
- Encourage model development

See notes --------

What we do in South Florida?
Developed an Object-Oriented surface water- groundwater model. Integrate both. Put all the elements in one matrix. Used XMLS.
Algorithm testing.

Potential Solutions continued…
Ease model use - students today want to "push button" and get answer
Encourage documentation.
Avoid improper model application

Calibration important
Sensitivity analysis needed, but not generally done
Solutions = more investigation
= publish standard guidelines (not sure is feasible)
Proper selection of spatial and temporal variables.
Standard guidelines.

Problems, continued;
Misinterpretation of modeling results.
Work with many ecologists and biologists problem seems to be misuse of model
Wrong application of the model.
Partial representation.

b. Natural Resources Conservation Service, Bill Merkel

Since 1960's using models.
Computerized instead of manual. We develop models to be used .We look at field and watershed scale models. eg. Flood plain studies, water supply forecasting, dam rehabilitation, water supply forecasts, non-point source pollution

Designing soil conservation practices, stream restoration.
Water table management

Models developed by NRCS are used by many other agencies.
NRCS involved in natural resources conservation on private lands.
Our model is simple to use, fill a need, can get support from different agencies.

NRCS has three different directions:

Management: need to convince to get funding.
Researchers: NR does not do research but rely on agricultural center researchers and universities.
Users: Try to use product and give feedback.

* There are questions involved in model development
What is it used for?
What are limitations and assumptions?
Where will I get data for it?
Who are potential users?
Model has to be developed friendly
What is the expertise of the users? We develop models for general engineers, technicians, etc. So there is a wide range of users.
What resource problem will it address?

One area we are really focused is involving the users. We try to involve users in model development.
Feedback from users is essential.

If the model is not supported it wont be used. Users need training.

WATER QUALITY Model evaluation --support- development process.

There is limited resource, staff, and money.

5 step process:
Group national experts
List NRCS models
Rate model components (high, medium, low)
Determined purpose
Decide which models to support

Partnership management Team === NRCS/ARS/CSREES

Team to coordinate Research and development (1998)

541 needs submitted in total: 1/2 resource needs, 1/2 technology needs

Began in May 1998, Ended August 1998

(PMT vision
FY 99 NRCS Initiative)

Water research needs were highest ranking importance to development

In Conclusion:

NRCS has a lot of model development in past but still a lot to be done. Working with Corps USGS. Willing to work with other agencies.

c. Hydrosphere Inc., Ben Harding

Appropriate use and guidance comes from the goal of getting quality results for whatever variable we are trying to calculate. How do you know that you are getting quality results? You have to examine your results.

Series of steps in testing modeling behavior are done. It is done but could be done more rigorously. We should be calibrating against the data.

The weather forecasters have a term that they call model skill. Look at what happened, compare to model prediction and evaluate. There is a need to check model against actual behavior. Would it be beneficial to run different models with different algorithms on the same watershed.
Examine the model prediction.

We need to pay a lot of attention to the issue of quality of results.
If you did not get good results then why did not you?

Two basic issues:
Education and model algorithm
Model vs. modeler

We are in the point of model use and developments after the first computers, 1960's.
Standards for certification of models.

If you follow the guidelines you don't get the right results necessarily because of missing the calibration
If you don't get the results with the model, it could be lack of education or the model itself was inappropriate for the use.

Everyone thinks that distribute models would be better, but how many pieces are enough? If you setup a watershed and make a thousand pieces of the land is that enough? Or 10000 pieces of land?
Can only independently calibrate small number of pieces for rainfall - runoff
How distributed do you get?

Modular system :
Favor the idea of comparing different algorithms within the model so that you can see if one algorithm behaves better than other. But the problem of education and calibration becomes harder.
Number of parameters increase.

It is worth to consider that it is not unreasonable to have an ultimate model with best algorithms for a specific process.

Physical system being represented is what it is and we have to arrive at a best way of handling.

d. OREGON STATE UNIVERSITY, Wayne Huber

Some assumptions about model users
Install the model, read agreement, do not pay enough attention,
With regards to the installation disclosures, in general we don't pay enough attention to them. If the models are free this is a bigger problem, if we pay for the software, we tend to read the documentation.

It is not practical to restrict model use to only those who are qualified.

To mitigate these problems:
Emphasize uncertainty.
To emphasize use bold print.
Provide honest recommendations for alternative models and procedures.

Indicate necessary level of training and expertise needed to use models
Perform sensitivity analysis and emphasize uncertainty.
Provide alternative models and procedures

The users are responsible.
Encourage communication, Internet discussion groups.
Person who runs the model is more important than the model itself.
Users manual documentation can be better.

Need help with parameters
Put parameters on the web
Encourage meetings.

e. LOWER COLORADO RIVER AUTHORITY, Quentin martin

Guidance and application of water planning models.
Experiences with Texas water development board.
Experiences for guidance and support.
What not to do in terms of application of models.

Agency history: Facility design, Reservoir operation (particular emphasis), etc

LCRA water service area..
Originates)

Use GIS work by Maidment.

Purpose of TWDB Models.
Technology transfer intended. After 1975 target audience was TWDB staff.

TWDB User Support and Guidance.

We would provide the data free but if they encounter problem no training is supported.

As the computing environment changed agency moved to the new technology, what the user would have liked.

Graphic user interface
Tutorial and case studies
Extensive ions and internal help function and online documentation

Continued model updates / correct

User forums.

Concluding Remarks

TWDB models little used even within TWDB.
TWDB support provided inspiration for later models.

QUESTIONS and ANSWERS
Qsn
Appropriate use and guidance example
3 agencies
Basin approved
Ran three models. Identical models. 3 different answers. Pure hydraulic.

SCS gave lower elevations
SURVEY highest
CORE(?) was in between..

Which one is correct?

Yet this is a physical problem.. When you go in to hydrology it is more complicated.

What would three agencies do in this case?

What do you mean by appropriate use?

ANSWER: model is a model it is not reality. We try as much as possible to provide some real data. With no consideration with real data you can get any answer. We encourage calibration.

Wayne Huber:
Compare the analytical solution

OBEY:
Was the difference significant?
Answer: It was significant

Qsn: distributed models.
How much is enough?

Comment:
Answer depends on the model. There is always a model bias.
In Hydraulics can we come up with specified cases with analytical solutions so that we can compare numerical solutions? Are their standardized situations that you can do fair comparisons to test.

Comment: neural network
Comment: Model verification involves not only calibration but also validation

Wayne Huber: In urban areas we don't have calibration data
More detail, better

LCRA-- if you avoid the idea of preprocessing within the model it will make much more difficult to use the model?

Comment: referring back to Dave's qsn
hydraulics and hydrology component
Where do we assume that Manning's equation is completely correct.

Comment: if I use a rational model and it fails is it the model's fault?
If people just use rational method why are we giving so much effort to develop complicated models.

NORM Crawford:

Comment: many C coefficients are high …
Cost billions of dollars.

Hoshin: Comment about validation:
What automatic calibration really means.
Calibration is a black box procedure? I don't agree with that.
How do we gain confidence?
Calibration procedures need to meet some benchmarks.
We are getting there.

…

COMMENT: Can we make models smarter to alert the user?

NORMAN: how can you tell if your results are good or not?
Guidelines are very difficult to write and to make sense.

Continued discussion from previous day. But focus main objective to:
Come up with positive objectives for committee as topics to be included at as or possible sessions or topics to be discussed in 2002 meeting.

Open up for first part (approximately one- hour).
Appropriate use of models….

How to get users to read manual (end of meeting).
In the agencies I have worked for they are not willing to put out training. Rephrase - money for training. A problem getting agencies to recognize this need.

NRCS training course, funding problems now need to pay for courses. Feeling is that makes no sense to put in effort for guidance and have no training. Would they be willing to pay costs - NO the courses have limited impact. YES - payment is not as critical an issue.
Agency by agency basis based on funding levels, need to justify to supervisor, do not think that it should be necessary to have training to use. Software should be stand alone. One help, have a certification program, may help state agencies justify training. Better to have something to document training.
Real carrot, required to have continued education for PE license.
NRCS problem for many years, how do we train, alternative training methods, web, teleconference…Maybe one session focused on training methods.
Ask professional agencies to certification use of program, one way to get people up to speed with use of program. Is this a solution?
Concern, modeling not like Microsoft program, running vs. usage. Just certification that person is a certified user, but may not solve the problem of correctly applying the model. Does not prove that you understand theory, limitations.
Short courses NRCS, cannot teach how to judge if answer is right.
Anybody can apply a model, but ask are you a certified user, at least means that you have been brought through it with an experienced person. Person teaching knows mistakes that may be made. Training is critical.
In NRCS, third party certification, have to demonstrate to independent instructor that they can deal with the situation, and one year later checked, is this reasonable? Second part If licensing someone that is reasonable, creating bureaucracy, do not want to get state involved.
Who certifies the certifiers?
Inspectors ok to have certified and overview, but can't do with models.
Similar to other technology problems. Variety of ways to do this, takes substantial bureaucracy to oversee certified modelers. Overall, premature to figure out how to give more than a certified. Review boards (such as in medicine) that review practices are in line.
Another possibility, set up problems on the web to run, take exams on the web.
One week course doesn't mean expert, but looking for position on private or public agency. Candidate indicate that they attended several courses, sends signal that individual is interested in attaining skills and knowledge. The image that would project would be useful for those who hire.
Have to go beyond just a certification. Want to ask is this group certified.
Sediment conference, Issue does any agency want to provide a course during the conference, may be a way to attract people, b/c they are there anyway. May be a way to reach people.
Would be real difficult to do a certification, Corp of Engineers does not even require that their the agency people have certification. Also the models are always changing.
Web issues, certified the people who are knowledgeable about model and make them be contacts for others on this model. Would people want to do this?
Yes, on chat rooms.
Would be a great way to provide info to users.
Would have to trust that the person would be qualified.
Organization would know who is qualified.

Some models that the agencies never answer a question for. Good if they can.
Maybe certification issue will not work b/c not a Microsoft program, effort go more towards communication real world problems trouble shooting on website lookup problems on websites. People post experiences on web, to see how other people solved problems.
Need support.
Private good, but pay a fee.
Problem certifying users, difficult, tone has changed since brining up websites, people seem to think tat it would be good. Another level the originator of model will monitor chat room, do not answer everything, but may respond to off-the-wall answers.
Originator can choose to answer if they choose.
There will be occasionally really dumb answers, there is a lack of knowledge in first responses.
Chat room or some source of information good idea, individual certification not practical.
Generally will use a model first before going to a class.
Need to move towards making help available, but cannot force people to do this.
There would be a need to evaluate the system and responses, do not want to create inefficiently b/c people not getting proper responses.
Summary:
Possibly asking organizers to have short sessions during conferences.
Further explore in 2002, have presentations at next session on how agencies are addressing this issue of proof of experience.
Lack of organization of inter-comparisons of models, do we need this?
Battle of the models, 5 models, water distribution network design competing on same problem.
Would like to see societies organizing these type of comparisons.
People like to point and click, developers should consider making it easy for users, help windows that make it harder for them to misapply.
Checklist, set of guidelines, key issues that go into programs.
Similar to paperclip that during bad pattern of use a helper is brought up to indicate the problem.
How are you going to program such a thing into a model?
A guideline issued by someone that a model should have in it before sending it out.
Software standard, documentation standard related to user - possible session.
Advantage prior to conference to use experience of community how they became familiar with models, where do formal teaching and classes fit into normal model use. Therefore can find out what may actually work rather than speculating, find out successful examples of training and learning in modeling community.
Three possible sessions on calibration, sensitivity and uncertainty analysis, need to verify algorithms/models.
Session, what to do when there is no data and can't calibrate directly?
Anymore panel subjects that need further discussion?
Comparison of capabilities of each model, create model information clearinghouse.
Difference between certifying models and certified modelers.
Get to world plusses and minuses of models, is this a good idea?
Yes, Not evaluation so much as gross indication of model capabilities - starting point.

Questions that engineers want the models to answer or how to perform, something like this would be good.
There is a lot of advance work necessary to make these meetings more successful.
Some type of certification of models will be necessary to meet with regulations. There has to be a standard.
Problem with certified methods they can get set in stone, which is a downside.
Can flexibility be built into model certification process to more easily move to new technology?
Happens slowly.
Is there room for standard practice for evaluating models.
There is something of this being done. Some uncertainty being done.
Have agencies sharing experience on how they meet standards, Faced with idea that cannot hold hand of users - user-beware - We put it out there, private says we put it up and we give consulting (Haested),
Hydrocomp software installed and run in real time, both software development and communication with users on how they are doing. Have distributed a lot of software, no way to control users. The interactive assistance web-based can be very effective if pursued, additional tools coming out that may make that better. To provide help need to see what user is seeing, new technology to put up screen that is duplicate of other person (2000 miles away). Tools we use in 5 years may not be what we have to use now.
NRCS dropped idea of having checklist before distributing program.
Is open code a good thing? Sometimes users can find bugs.
Proprietary models are a problem because we cannot evaluate the model code.
Guidance for use of models, need guidance with physical basis would be helpful to users of models.
Is there a checklist that the developer has checked the routines?
Publish algorithms that are used for processes, way to protect proprietary code.
Solvers will not be released.
Verification numerical algorithms prove application of model. Problem with large numbers of parameters - automatic calibration not very easy.
Need to know regional methodology for calibration. How do you make reasonable assumptions of where to start?
Guidelines for calibrated models.
Short course at a session, introduction to certain models, computer demonstrations.
First one - introduction overview, demonstrations, limitations.
How do you avoid vendors putting out slick presentations?
Problem for those that are not picked to be presented, session related to models all afternoon everyone has a chance to demonstrate in the evening.

Summary

Certification discussion, development of bureaucracy training certifications required, good results bulletin boards chat rooms, FAQs, session of those who tried the techniques how they worked and succeeded. Concurrent courses establish guidelines for developers to meet, min requirements for documentation from user viewpoint - validation, limitations, where applicable. Sessions verification of models. Session validation of model with limited or no data. Agencies need to be aware that training is important. Guidance based on physical questions, also publishes physical code, hide GUI code.

BREAKOUT SESSION & DISCUSSION - PANEL 4
MEASURES OF MODEL PERFORMANCE

George Vellidis – **University of Georgia** Bio and Ag Engineering Dept. (90 scientists at U.Ga and 40 at ARS).
College of Ag. Has to address lots of unfunded mandates.
Southern region project group – brings people together on yearly basis to address issues
S-273 regional project research project – development and application of comprehensive agricultural ecosystem models.
http://www.sahra.arizona.edu/ . Southern Assoc. of Ag. Experiment Station Directors, with model evaluation on this web site.
Other partners – American Agriculture Committee, ASCE Environmental and Water Resources Institute (EWRI).
Focused on development and application of comprehensive ag. ecosystem models. One project is coordination comparison of ag. Transport models. (see previous web address … /Model/Proj/index.html).
They spent 1.5 years figuring out how to evaluate and compare about 30 models. Without extra $$ people were not willing to use the same data and conduct the same application. The ASAE Tech. Comm on Hydrology, ASCE, and Env. And Water Resources Institute all gave some money to encourage cooperation.

Models (Agriculture Non-point source water quality models and others ~ 18)
Evaluation of models
3 applications of models – 3 papers to be There will be papers on (1) the 30 models, (2) the criteria, and (3) matrix evaluation of the models using the criteria

Criteria:
Intended uses/purposes/objective of the model
water quality and hydrologic characteristics addressed
model scale
economics
Target audience: modelers/novices/agencies
expertise require
Model characteristics
verified applications
interpretation – how good is it?
Input/output
Source and avail. Of models
Continuing education / training opportunities
Versions
Interfaces
Input/output options
Data requirements
Methods
known limitations and applicability of model
others???

New evaluation project – S273 done Oct. 2001
Development and assessment of TMDL planning and assessment tools and processes
Objectives of project:
Develop - improve and evaluate watershed models for TMDL
Assess economic benefits and costs and equity issues
Assess the potential ecological benefits / implications
They want to recruit participants, but $$ is an issue…

Dave Goodrich – ARS
Measures of Model Performance
Opinion: our modeling and computational cap. have far outstripped data networks and our ability to describe states and fluxes of the hydro cycle and ability to collect data (distributed watershed observations) and to comprehensively assess them.

Measures:
Point and small scales – physically based models work well.
Challenge – variability and heterogeneity
Distributed models – require dist. observations
States and fluxes
Dimensional mismatch
D (par. Space) >> D (Obsw. Space) Results in misidentification and miscalibration
In some cases – traditional measure are even difficult to get (southwest regions)

Walnut Gulch (Tombstone, AZ): convective storm issues – runoff-producing storms – RO per unit depth becomes smaller as increase area. In SW areas, runoff observations are inappropriate.
Observed runoff depth < Rain gauge accuracy (noise to signal ratio = large)
Need other observations and other approaches (physical constraints)

2002 meeting – advocate session on new observations. (data and instruments to support modeling)
Beyond traditional instruments and measurements:
- Inexpensive and reliable instruments and sensors
- Remote sensing (ground, aircraft, satellite) – (e.g., SAR and LIDAR meas. To measure channel morphology)
- Model derived (eq. Atmospheric)

Lot of effort going into modeling and software – need more effort on getting better observations!
Behind on our efforts in this field!

Hydrosphere, Inc. – Ben Harding
Focus on water resource systems models
Hydrosphere – water res. Planning consulting firm
- Founded in 1982
- Initial focus on planning studies

- Ext. use of water res. Systems models
- More recent practice in water quality and groundwater

A. WR system models –

Characteristics:

They are application models (e.g., reservoir needs, pumping systems), designed to answer policy questions

The model developers have better access to the physical structures and processes that make them work – usually better access (physically inspect system, talk to operators, aerial documents)

Consistency – the systems they model are not as consistent as natural systems. each case is unique. but not as consistent as other models. / policies that drive needs are very different on each river / policies also change over time.

Complexity and diversity – less complex than physical models, but may not be less complex when dealing with the interface of water quality and/or groundwater with policy / but some integration (groundwater/water quality) models. Fewer parameters mean more sensitive pars.

Issues:

Process representations cannot be generic for all rivers. They are always writing new code and rule sets for unique situations (and "software doesn't get stronger as it gets bigger").

Process pars. Change with time – operating rules change (sometimes even from shift to shift)

Often no data for verification / calibration – and modern data are NOT consistent with old data.

B. Validation and verification:

Dark View – impossible!!

Realist view – what is good enough? What do we need to support the results? More precise models need evidence to support "Are these results wrong?" That's the question that always comes up in legal depositions. The scientific answer is "of course they are", the legal answer is "what do you mean by wrong?" It comes down to, "What do you need to support the question you've asked?" You have to look at the "weight of evidence". When more precise answers are required, then more evidence is required.

What good are models?

Quantitative estimates.

Formal framework. This is a major "good thing". It forces users to think in a structured way.

Sources of insight: models are heuristic tools / can gain insight.

C. Evaluation of System models:

- Requirements phase – highly interactive with client, formal, provides mutual education on performance / quality of models, can last weeks to months.
- Mass budgets and fluxes – global and segmented Lots of models don't conserve mass, let alone energy!
- Graphics and statistics are crucial – GIS has been good tool to find problems.
- Sensitivity Analysis – very valuable / help to define models.

- Peer review – not used much in WR – should be implement – important issue. Peer review is used in academia and legal venues, but NOT much in water resources applications. Need to do this more – follow the example of the structural engineering community.
- Quantify confidence of estimates – build in Monte Carlo capabilities?

Illinois State Water Survey – Misganaw (Mike) Dimissie
What is appropriate model for Illinois Basin (state perspective)?
Perform data collection and research in support of state government (water quantity, quality, groundwater). Agency funding has been cut a lot, so they stopped model development, model support, and model training. Thus, they have become end-users; and use existing models for research purposes – developed and supported by Fed. Agencies (they are now users of federal models).
Decision to decide which models are best for their system – large river basins The problem is that they can't just take USACE or ARS models that were developed for small basins and then apply them to large basins. Nor can ISWS afford to do the research to scale up those small-basin models.
Have data for calibration of small watersheds – but not for larger system – what calibration and verification Is appropriate for large system
State agency – need models for multi-purposes / combine models to answer all needs? Or use specific models for each one? They are really looking for guidance on how to combine models from different sources to answer multiple questions (flows, floods, water quality).
Illinois river basin drains around 40% of state – highly regulated river. / major lock and dam system. Has experienced tremendous channel change and is now highly regulated. Typical hydrologic models are not designed to handle this. Have hydraulic model for main stem – hydrologic model for tributaries – how to link and use together to model entire system. The modular approach is probably the right way, but they are still evaluating it.
Calibration and verification of model – hard time to decide which data set is appropriate for verifying model. Calibrate each subwatershed / how to compare to cal. of mainstem to smaller watersheds?? Major calibration problem. Need help on these types of issues. Should they calibrate across the small basins and then combine with the separately calibrated (or jointly calibrated?) mainstem?
He's posing questions because they have no answers… ISWS is having a hard time deciding what to do…
Also have water quality needs – need models for this also.
Can choose best hydrologic model – but is that model the best one to go with the water quality model – how to interface two different models. Will the "best" contamination model be compatible with the "best" transport model? Will they be compatible with the "best" flow model? And on and on…
Problems facing at state level – more broader issues than just hydrologic modeling – decisions, management, much broader / tougher issues (main problem: how to jump from smaller scale models to large system models).
Recommendation: research community needs to pay special attention to going across scales and across subjects (linking).
He's glad to be here ☺

Soroosh Sorooshian - University of Arizona
Background has been in model calibration – but now getting into other issues. He's moved from "how to do calibration" to "why calibration is important".
Future meeting – maybe delve into components that make up models.
Recommendation: for future meeting: focus on components that make a model useful for its intended purposes.
Modeling puzzle – have several components – model, data, parameter estimation
Parameter estimation must precede validation!
But need to keep in mind user sophistication – requirements!!
Calibration of model – context of universal set – basin is perfect / model=how far are we from truth.
Range of parameters – want to be as close to model representation as possible – boundary closer to truth (basin) How far you are from "the truth" depends on the model.
Calibration should put the model at the boundary of its limits toward getting at "the truth"…
Requirements: Calibration components needed for:

Objective function
Sensitivity analysis
Search algorithm.

Optimization procedure – make best improvements you can.
SCE – want to find minimum in response surface. Global versus. local search algorithms. Need combination of random search and global search with simplex. SCE vs. simplex – 1000 random searches – SCE finds true optimum.
The competition between manual and automated calibration is rooted in the limits of past search algorithms and objective functions.
NWS work – comparison of manual and automatic techniques.

Work with RFCs to see advantage in automatic techniques.
MACS procedure – est. low flows first, then concentrate on high flows, then fine-tune baseflow.

estimate again. – single objective process.
Multi-objective really the future – models with multiple processes / objectives. Use different objective functions for different components, and different data for different components.
The surrogate worth tradeoff method has long been covered by Yakov Haimes in all his courses. We want to have both parameters minimize an objective function, but it's better to ID a Pareto set. That set identifies the uncertainty in the parameterization.

Definition of pareto set – how to calibrate multi-objectives in function space
Can estimate errors in models also.
Application to LS models (BATS model). much better estimation of 4 fluxes using MO calibration.

But – application of MO to single flux in most hydrologic models, you don't have lots of data available; often only flows. So…
Separate hydrograph into 3 sections (rising limb, fast recession, slow recession) – use objective to estimate each region.

Obtain “pareto” set with region of parameter space to estimate region of best hydrologic flow – trade-off space. The range of predictions that result from using the Pareto set, then communicates uncertainty in model estimates.

Key issue also - precipitation data (especially in Arid/Semiarid regions): most important input to models. Especially difficult in western US – blockage with radar (due to mts.), poor Z-R relationships, sparse gage network, snow sampled at low elevations, but occurs mostly at high elevations.

Need satellite estimate to get better estimate of rain – multiple source rainfall estimation.

Hydro. Community has typically been silent in requesting better precip. Re: NEXRAD development Inputs – support for satellite / Nexrad research.

Need to be more aggressive in needs / support Hydro community needs to rescue NEXRAD data… for a long time it was just thrown out because the focus was on storm warnings, not hydrologic research.

But NEXRAD is not the only thing… PERSIANN vs. RAMS models – 25 km resolution (future – 4 km). NASA priority to develop! Precipitation estimation is the highest priority of upcoming NASA efforts. But hydro community input is largely absent. The atmospheric folks have been the primary drivers. It’s OUR responsibility to fix this!!

Precipitation mission – Hydrologic community support has been minimal – need to be more supportive (climate community has been very supportive).

GEWEX /GCIP (only about 1/3 of the folks indicated they had heard of GEWEX or GCIP) Hydro community must be better aware of these things – brief overview – determining earth’s hydrologic cycle and energy fluxes using global measurements.

Model the global hydrologic cycle and assess its impacts.

Develop ability to produce variation in global climate.

GEWEX objectives:

observe elements of global water cycle,

global model development,

develop predictability of regional conditions, and

new observational techniques.

GCIP changing to GAPP. Focus on seasonal to interannual, and on going from global to regional to local applications. Our voice (hydro modeling community) has been absent in giving input to these giant research programs that are always pitched in terms of being of use to the water resource community.

Application from Climate down to Water resources management –

Need more support from Fed. Agencies – esp. hydrologic from the community.

Future session: to bring together designers of large system modeling to the needs of smaller systems (hydrologic community).

END OF PANEL PRESENTATIONS

Questions:

EPA initiative – ETV (Environmental Technology Verification Program)– under office of research and development. Looking at hardware Best Mgmt Practices (BMPs) and ETV

protocol for verification of environmental models. Will be used to evaluate several of EPA models – verifying that models do what they say they will do.
Available in next year or two – results will be on web. User community can have influence. They have a website somewhere…

Use of models – ability to be able to swap components in and out of models – need more flexibility.
Verification – need to have clear statement of limitations of models. Should provide test and verification documents of models – can determine capabilities of models.
Advertisement for ASCE Committee on River Hydraulics Modeling.
ANSWER: models are very case dependent, hard to make them all generic to fit together.
Are activities going on to document models and improve future research?
ANSWER (Soroosh Sorooshian): Modular modeling system – ease of use for plugging components together. Users need to read limitations of model components – what is capable of being linked. Because models are complex, there's no standard set of limitations. It's not something an individual can do, because the models are so complex that it's teams of modelers that would have to answer those questions.
ANSWER (Goodrich)– important to publish limitations, but many don't read them. Better guidance on models would help users - better documentation and help files. Users want more on-line. The ease of linking models (using MMS) increases the danger of improper modeling.
Ben Harding: You can't stop idiots… He likes the paradigm of Turbotax. There's real opportunity for commercial vendors in this area, because users WANT more and more guidance and help, conceptually and tech support.

QUESTION: What is status of model performance measures?
ANSWER (Soroosh Sorooshian): Issue not resolved yet when looking at hydrologic models. Skill scores used in meteor. modeling for a long time. Example: they can say "7-day forecasts are now as good as the 5-day forecasts were 5 years ago". Eventually in hydrology – will have to address how to measures (AHPS in NWS). Need to set timetables to measure how models are performing. May need a session to address more directly.

ANSWER: Many users of TMDL applying models when they don't fit application. Affects performance of models if not applied properly. Because of the new TMDL rules, there's a "feeding frenzy" in the private sector that's creating a real problem. They are grabbing at any model they can find. EPA is not vetting the models, they are just accepting anything!

ANSWER: Ephemeral streams (TMDL) – not an issue in the west – can EPA regulate in west on this type of climate.

QUESTION: How does panel feel about model uncertainty / data uncertainty? What about uncertainty in the DATA (inputs and outputs), not just calibration uncertainty?

ANSWER: Goodrich: GLUE procedure = brute force Monte Carlo procedure "it's incredible that we give hydrographs without giving error bounds"– assigns uncertainty to

models and data and parameters. Many communities appalled that no errors associated with forecast hydrographs – other communities have uncertainties in model forecasts.
ANSWER: ISWS: Standard data sets can be used to test models against – used in Illinois? Urban runoff community tried developing standards where your model would be tested against a standard data set(s).

QUESTION: A decade ago there was some discussion that needs to be re-addressed. What is the role of calibration when the input data are inadequate (esp. precip)?
ANSWER (Soroosh Sorooshian): What other option do you have?

QUESTION: How reliable and appropriate are automatic calibration procedures when data is bad / input in questionable? Better parameters on process and not on inputs. It's better to parameterize on the process, not on the specific data set.
ANSWER: Besides automatic calibration – what other options to you have? You either specify pars. Or use manual calibration to adjust. Use observable parameters first before going to calibration procedures

QUESTION: Large scale simulation models – natural system model (south Florida) – How do you do uncertainty analysis of spatial data (e.g., topographic map) – how to address uncertainty in spatial modeling? How to do Monte Carlo assimilation on spatial data?
ANSWER: Goodrich: Many limitations in addressing this – any standard procedures? Some standards set up to address this with USGS top. Data – clear guidelines and stat. Material to describe data. Very limited data on this – usually brute force methods. GIS standards have been developed. Need good metadata (source, accuracy limitations). There are fairly good guidelines for topographic data.
ANSWER: hire a good historian…
ANSWER (Soroosh Sorooshian): when you go way beyond available data, you are in unknown territory. There's little good advice

QUESTION: How do you do a spatial Monte Carlo analysis? Example: they are trying to look at "calibrating" land use. How do you arrange land cover differently?
ANSWER: Goodrich: There's no good answer. There are some structured ways, mostly brute force. No good, elegant ways have been identified yet.

STATEMENT: You can put more complexity in models, but you can't make them better. The model error is so great and the data are non-existent. SO there can't be any sensitivity analysis to say how good a model is. All you can say is how bad it can be… Simplicity of models: model error, parameter error, data error, - all sensitivity analysis and calibration can only help so much because data and model error affect outputs. Sensitivity analysis doesn't always improve model – but can tell you how bad a model is.

ACTUAL BREAKOUT SESSION – PANEL 4, on Thursday, November 9, 2000.
Objectives were outlined in Workshop agenda.
Moderator: Jeff Holland, USACE.

George Ives
Comment: His perspective is from involvement in the national forest products industry. They're concerned with HOW do we develop criteria to evaluate models and select them.
Comment: Which models are our institute going to use – interested in model comparison. Have series of steps (peer review, sensitivity analysis) to evaluate models. Trying to develop quantitative measures (not models) that combine consideration of the Pareto set with the Turing test – combine Pareto set with?? artificial intelligence methods (Turing test?). If machine response is indistinguishable from human response – that equals artificial intelligence. Models have different responses for different events – develop Pareto vector that model must meet – peak flow, low flow, timing, etc…. – use TURING test to evaluate (0= not in confidence, 1=within confidence limits).
The Turing test can handle the notion that data has lots of scatter… how do you test the model, given highly scattered data. If model response is w/in the data scatter/confidence, then you would ACCEPT the model. The key is that you need to identify you critical questions re: performance, then apply the Turing test to each criteria. You'd give each criteria a score of 1 if it passed the Turing test, and a score of 0 if it did not.

Dave Goodrich:
Should these tests be published with models, or published as a separate paper/effort?

George:
Multiple step process – needs to be tested in various modes. The first step is to publish model development. The 2nd step is to publish analysis of the applicability of the model to your specific situation.

Hoshin Gupta:
Is model suitable for what I'm doing?
Is model suitable for region using??
Is the model doing what we want it to do?
Study to evaluate how many and what kind of watersheds are out there. Effort now to create set of data from around the world.
Hydrologic regimes are so varied. Someone needs to characterize them and state, "There are X number of hydrologic regimes" and then create a set of representative watersheds around the world.

Pete Hawkins:
Hear! Hear!/Yes! Yes!

Dave Dawdy:
Thinking in terms of historical development of models…
Comment: You can only go so far in improving model components – than link models to things they aren't originally designed for. The big problem is that we link hydrologic models to all sorts of "god awful" things (e.g., sediment models). What criteria do we have for linking models? Hydrologic models will "generate" TDML. What criteria are important (e.g., fish kills, low flows, peak flows, mean flows)? What criteria do we have for optimizing joint models of hydrology processes? Flood forecasting vs. water quality

(TMDL) – hydrologic models used to help predict TMDLs. What are criteria we are trying to test models against?

Pete Hawkins:
Flood output, water yield are not the critical thing, but soil moisture that causes hillslope failure. Soil moisture regimes are important to ecologists too. Our engineering bias makes us focus on outputs, when we should be focusing on the critical state/flux, or learning what is the critical point (location) in the landscape.
Comment: Need to look at interior processes of models (where payoff is) – Academic communities can help investigate this. Engineering side tends to look at outputs – but maybe need to more focus on model design.

Hoshin Gupta: again, is the model right for the right reason?
Dave Dawdy: SCS abandoned their model for the wrong reason (strictly lack of $$)

Dave Garen - NRCS:
Distributed modeling perspective – proposed session to look at new and different types of data to support the evaluation process these types of models. He said he would be willing to put stuff together for a proposal/statement.

Dave Dawdy
Comment: Study on Apache reservation – soil moisture study. Looked at paired basins throughout the reservation; they had soil moisture probes "everywhere". Model behaved differently depending on what model was optimized on – to predict flood, needed to overestimate actual soil moisture. Optimizing on soil moisture would cause model to miss the floods. Need to have data on internal processes – to better simulate processes.

Hoshin Gupta: there's a bigger problem, too: soil moisture in the model versus soil moisture in the field.

Dave Garen:
Is the model structure really what's going on? Maybe the runoff generating model is inappropriate for the purpose used, and you're not REALLY getting the right pathway to the stream (thus erosion and water quality constituents are not right).
Comment: Basic RO generating models inappropriate – getting right answer for wrong reason. Models limited to Hortonian overland flow, but they (e.g., EPIC, SWAT, etc.) are being applied "everywhere"! – but need different processes for climate regions.
Model verification – does model contain the right structure for the right process being applied to – match dominant processes Do we know the dominating process?

Hoshin Gupta: with George Leavesley's MMS, you have an ability to do that…

ISWS: How to connect inputs/outputs for models that are hooked together – chose best sediment model, best hydrologic model – but is output from one consistent to be input to another. People are too focused on the data management of models (inputs, outputs, units, time scales, etc.) and their linking… they are not focused on PROCESS linking.

Dave Dawdy: Hortonian flow issue – Geological Survey – model builders need to actually look at basins. Need to learn about actual processes. He has worked w/ VJ Gupta. They were talking about partial contributing area versus/ Hortonian flow… Went to headwaters during a big rainstorm. There was no water in a swale, but it was flowing off a hillslope. Modelers need to "go out in the basin when it's raining, and get wet". If you believe in partial contributing area concepts, then prove it! (A CHALLENGE… ☺).

Hoshin Gupta:
QUESTION: How do Hydrologists view problem; people look at a whole host of model performance measures; calibration (until recently) has not…

local measures – peaks, recessions, onset of hydrograph, timing

Global measures – overall bias, overall RMS on simulations (NSE)

Hydrologists looks at whole host of problems

QUESTION: How does Mathematician view problem? Hydrologists may be interested in this perspective, but usually not explicitly and they don't know the relevant criteria… Precision (how narrow are bounds), Accuracy (close tracking of data), Parsimony (simplest model to do job), Identifiability (from available data), Consistency (if model is wrong – is it consistently wrong) == PAPIC

Doug Boyle's work… looked at how NWS hydrologists calibrated models
Levels of parameter estimation:
Level 0 – use data off maps, local hydrology
Level 1 – identify certain parts of hydrograph – recessions, etc. identify one parameter at a time
Level 2 – go in and tweak parameters, deal with interactions of parameters – Automatic procedures are best here (with correct guidance

Split sample testing
Calibration period --- validation period
Statistic for each period. (ex. RMS for each) – meaningless because you only have a sample size of one for each period…– need to look at consistency of performance over periods. Look at individual yearly stats. For each period. Plot against mean annual flow – Drier years – lower RMSE, Wetter years – higher RMSE
Do for each calibration period, verification – if plots line up (same line) then model is consistent.
If calibration is designed properly – should get consistent results in both periods.

George Ives: but you'll always get lower RMSE under calibration than testing…

Hoshin Gupta: not if you use multiple objectives. MIN(rmse) and you increase bias, MIN(bias) and you increase RMSE…

Dave Garen: Proposal – session on advances in calibration procedures!!

Dave Dawdy: but it happens because of the size of the flows (low flows = low RMSE)
C: should expect RMS to go with magnitude of flows

We do it this way: Split samples use A to predict B. use B to predict A. = cross validation. How to use together – better insight on models. Cross predict with each set.

Dave Garen: To get models past fitting exercise – does model extrapolate properly – predict beyond regions of model calibration. Take the big events out, take the small events out, then do the split sample validation…

MODERATOR: Measures of model performance part of 2002 conference. "This will be a major focus on the 2002 workshop." Will include separate subjects to address. Possibilities: New observations, data (for distributed models (Dave Goodrich)) – instruments to support

Pete Hawkins: Do models contain the right processes? Whether models contain processes – model appropriateness. Include not just river basin models, but all the process models, too. We need to confirm process descriptions.

Dave Dawdy: I came here because of sediment transport concerns, where folks make use of the "hiding factor". We're talking about optimization, but there's some situations where the process model is SO wrong, that no amount of calibration will make it right! Pete Hawkins: apparently, we can take the pieces, stick them together, calibrate, and then get everything to work…

Hoshin Gupta: I propose a study: Evaluation of standard hydrologic regimes that exist. Need sampling of watersheds Need to identify a couple representative sample of each regime, and then have folks focus research on those basins.
Then evaluate models that can work with specific processes – types of watersheds.
Needs to be some theoretical work on types of watersheds
Moderator: these thoughts came up in the 1998 conference in Las Vegas. WMO did something like that in 1997/98 re: flood forecasting models. They used a common data set. Then the question was: How to compare models – What kind of criteria?

D Goodrich: DMIP is making some progress like that… We need to identify basins dominated by (for example): groundwater, snowmelt runoff, arid regions, and karst. Tougher test – test on different regions – semiarid, snow, hortonian flow, etc.

Dave Dawdy: (Consultant)
25 years ago – USGS collected data on various small streams, for flood frequency analysis on small basins. They collected meteorologic data, but it's hidden away because of competition with the NWS. They hid things by calling the data "Unit Values Files". (Unit Value Files) – if you access – has small watersheds all around the country. Used to evaluate flood forecasting. Need secret code to access data.

Ben Harding: his company thought they would get the UVF data, but it turned out to be not so widespread as they thought. There's a problem at the top with USGS that keeps them from releasing data. Linsey forced USGS to publish some of it, but that's different than availability. The institutional memory still exists regarding their conflicts with the NWS… Harding's company wanted to archive the UVF data, because the USGS data

storage tapes are decaying. The data don't have much commercial value, but they have "plenty" of total value.
USGS has a lot of valuable data (Unit Value Files) – but getting stored and not used – how to access data so hyd. Community can use.
Ways – pressure through ASCE / pressure through Congress.
Historically – USGS is resistant to releasing data.

Advances in optimization / calibration??

Leader: Let's shift to other questions…

ISWS: Is there way to come up with overall performance measures? Is there a way of evaluating performance for linked models? We seem to be focusing only on hydrologic models here…

Dave Garen: No, we need to focus on process validation – can evaluate whole, can evaluate pieces, etc.

Hoshin Gupta: We've got a lot of process descriptions, all developed at point scale; need calibration because point scale models being applied at larger scale. How to evaluate at large scales. How do you validate point scale processes?

Dave Garen: Evaluating outputs as well as internal structure / at range of hyd. Regimes
You need all kinds of other data: GIS, land cover, DEM, etc. to decide if the process was appropriately cast…

Hoshin Gupta: there is precedent in the atmospheric research community. They found that performance degrades when you couple models. Thus, they evaluate the components separately.

Comment: ISO requirements that Europeans have to evaluate models. Look at individual processes to see if model meets / verify application use or description of process. ISO looks at whether your process is producing "what the textbooks say". You can do that for all the point processes. But then the question is whether you are representing the application right…

Hoshin Gupta: Many models are not meeting physical process descriptions – ex. SAC model (conceptual model) If you followed the ISO requirements, you'd have to eliminate a lot of models that are being used operationally (e.g., SAC), because "tanks" are NOT the right process…

Comment: he comes from Forest Hydrology, where their problem is trying to predict impacts of changed conditions vs. natural conditions (e.g., land use, forest conditions, beetle-kill, fire). If they are going to predict impacts, they had better get the process right.

Comment: Hydrograph – not only have to validate Q, if forestry involved – need to evaluate changed response if changes in landscape. Model needs to be able to adapt to changes in landscape, Need to do historical modeling in some cases – to evaluate. Need very good process description for modeling / simulating changes.

D. Goodrich: the error bars around a hydrograph may be as big as the curve or the difference between curves.

Comment: we do have experimental watersheds…

David Dawdy: As long as models give right direction and change – if models not calibrated properly – then ok. If we're after a relative response (rather than absolute response) then that's easier to do…

Hoshin Gupta: Different model performance measures for forecasting than for landscape changes / responses. There may be different performance criteria for relative (simulation) vs. absolute (e.g., flood forecasting) modeling.

Back to sessions:
New observations, instruments to support, evaluate. Hydrology. Models
Existing data
a. standard but increasing it's availability and usability
b. Agency specific data – what is out there? Research data/ operational data that is not available. "obscure data"
    Ben Harding: USACE has ~1500 rain gages.
c. Documenting data quality
metadata for time series data.

Vellidis: what's the process for deciding who gets to speak/present at these sessions? We need to do some good screening to get focused presentations, otherwise you end up with the usual blend that you get at other meetings, with everyone wanting to talk about their project, not the difficult subject.

Moderator: hey, don't look at me… I'm retiring…

Ben Harding: Need to extend metadata documentation – quality of data documented. We need to extend metadata standards to apply to time series. Federal agencies are required to document their data, but not their time series.
** some invited, some general topics that papers can be submitted.
** need to be screened so keep session focused.
** specific committees to cover topics
Panels will be asked to set up entire sessions

Hoshin Gupta: Also needs standards for model performance / validation of models. As community – need minimum procedures for evaluation of models. We need more data… great, we'll always be saying that! What we need are standards for the modeling community, minimally acceptable procedures for model evaluation

George Ice: Need more comparison studies / like EPA and southern regional ??? studies presented in morning. He likes the thought that there are different model uses, and that would affect the standards.
Few studies with evaluation

Comment: ASCE task force for data base for calibrating sediment transport models. In ASTM standard now. Set of parameters that need to be collected before can even start. Need standard for GW models – ASCE has –
Hydrology subcommittee has chance to establish some guidelines – have members review – at conference to discuss – goal of getting into ASTM (ASCE) standards. The ASCE Sediment Committee looked at developing data sets that could be used to evaluate models, and results have now been turned into ASTM standards. Some ASCE committee has also written standards for groundwater models. How about working on this (over the Internet) before the next conference and then using the conference to formalize/decide. Then he can get it into ASTM.

Hoshin Gupta: Maybe need an institution (NSF) to fund work – collection of basins, development of standards. Lack if $$ for this has hindered development of standards. The NSF needs to fund work to get data together.

Dave G: George Hornberger on committee. Just being published – report. There is a new initiative on experimental basins. George Hornberger is the group's chair; Roger Bales is on the committee. The federal agencies anted up the $$, but different data is collected on each experimental basin. Now they want to take it to Appropriations and get $$ for collecting common data and measures call for need of 10 global validation sites.

George Ice:
GEO-2000 thrust at NSF – seed money to get consortium at Universities to decide what data need for research, what different regimes are available. Also to determine representative basins from different regimes. The critical question is: What data do want to collect, and why? What do we need?

Ben Harding: What do we mean by standards?? Are we talking about standards for modelers/developers, or standards for appliers/users? A volume on model standards – would be very useful. Like previous volumes on data. A "Modeler's Handbook" would be beg and expensive, but it would be useful.
Another session – establish standards for evaluation of models:
Hoshin Gupta: Models standards – handbook product?? 2x2 table, because all 4 are different things
Model developers: Forecasting and Simulation
Model users: Forecasting and Simulation

DEVELOPERS -- Forecasting and Simulation
USERS – Forecasting and Simulation

Ben Harding: it would also be useful to get a list serves going for the different models and then use those to keep track of the community discussions. Process those discussions to extract things that come up over and over. Wayne Huber runs something like this for SWMM; they are an active group.

Mike Dimisse: we used to divide things into Urban, Agricultural, etc. watersheds. Should we revive that?

Reviewers of models / papers:
Guidance to journals.

Hoshin Gupta: How representative are the "test" data, compared to the full range of possibilities?
Sets of the full range of hydrologic regimes?

Dave Garen: There are so many combinations… we need to go to MMS, with a focus on the processes.
There's no way you can find a single model that would handle all the different regimes, so you have to focus on the processes.

Dave Dawdy: if the focus is on processes, evaporation is a constant in the East. We're using parameters to fit the wrong process.

Dave Garen: but then which description do you use to describe which process? There's the process, the description, and then the computation (analytic vs. numeric).

Hoshin Gupta: the atmospheric community has skill scores, because they're concerned with very specific things, with narrow goals. In hydrology, are we too varied in our applications to have standards?

Dave Dawdy: well, the weather folks came from a culture/education where they all studied/trained under the same "guru". In hydrology, we use consistency for determining flood frequency not because it's right, but just for the sake of consistency. There are too many competing interests across agencies.

Moderator: happy reminiscing about the Water Resources Council… ☺

Dave Dawdy: yeah, but Congress told the WRC to standardize in 17B!
The atmospheric community is unified. Hydrology agencies have to agree that standards are needed and will be used.

Comment: Model intercomparison – what went into comparison –
To what degree will users buy into performance standards – climate community has skill scores – have more specific goals. Hydro. Community does not have – operational people do not necessarily want standards. No "GURU" that entire community looks up to establish standards. Too many different communities / agencies. Difference of "science" vs. "engineering".

Comment: Two issues:
Standards are necessary – how to develop them / which ones they use.
How to get people to agree that they will meet standards.

Hoshin Gupta: for every paper review – need simple standards. Get journals to get put into review process.
Ex. Is model calibrated, did they run these statistics, etc… Peer reviewers need to start this cultural shift, that there are standards that modeling papers will have to meet to be minimally acceptable before they'll get published. The impetus for these standards needs to come from the journals and their editorial boards.

Dave Dawdy: but there aren't any of these folks at this meeting!

George Ice: Peer review process – demand for additional peer reviewers, but negative reward system for reviewing. More reward for writing, publishing, etc… How to get reviewers to agree on standards. The rewards for peer reviewing are meager, and there are even negatives to being a reviewer. That's why we have multiple peer reviewers.

Dave Dawdy: The most prolific writers are often the folks that won't take the time to review other papers. It's difficult to get real critical, detailed reviews. Important to have critical review – opportunity for improvement in writing / research.

Hoshin Gupta: A recommendation: draft guidelines for the review process. The group should write proposed standards and publish in prestigious journal. Use conference(s) to get other journals to accept, with short editorial piece for each journal.

Pete Hawkins: yeah, limit the number of parameters, like everyone does on regression models

Hoshin Gupta: but Luis Bastidas has shown that you can fit up to 30 parameters if you have different types of data.

Farrell: we need to talk about the inadequacy of existing data bases. National reports keep saying that spatial heterogeneity has to be addressed, but there's not a lot out there. Identify the limits of existing technology, and value of new data. WE need this to get $$, support for new databases. How are you going to determine movement of contaminants into the Gulf of Mexico, and the impacts of mitigation, if you don't have the necessary data?

Hoshin Gupta: recommendation: all models should provide outputs with uncertainty estimates. Users want uncertainty estimates.

Dave Dawdy: no, end users just want a number (e.g., for culvert sizing). End users are not the "big systems" anymore, where uncertainty is critical. Now they are small projects, where they just adjust after failure (e.g., culverts).

Dave Dawdy: People have been using random search algorithms (e.g., Rosencrantz methods) since the 1960s. Folks have been doing "advances in calibration" for 40 years… that's not the issue. The issue is identifiability, identification of models.

Hoshin Gupta: we had a session on this at the Fall AGU meeting, but participation was abysmal.

Dave Dawdy: that's because it's too new/unknown. People want to pontificate on stuff they know about, not do new work… The problem of identifiability increases when models are lined.

Pete Hawkins: agricultural engineers want zero runoff from irrigation
…. The session just runs out of steam…
Vellidis: a personal remark to us: This session is dragging! There's no organizing question/structure

Summary of proposed sessions:

New observations and data
Instruments to support
Evaluation of Hydrologic Models – on various hydrologic regimes / climates
Existing data
Standards
Agency specific
Research vs. operational
Documenting data quality
Ex. Metadata for time series data
Establish standards for evaluation of models
Model Developers: Both forecasting and simulation
Model Users: Both forecasting and simulation
Review of models and papers – guidance to journals
Internal documentation of models
Error propagation for hydrologic models – GW, Reservoir, WQ
    Identification of models – identifying model parameters
types of processes
where appropriate or not appropriate
Uncertainty estimates – data, model, parameters??
Require model error estimates to be accompanied with simulations
Require sensitivity statements (Monte Carlo??)
7. Advances in calibration techniques – current and new technology
Model calibration and evaluation

Conclusions/Recommendations
(Note: this is what was extracted from notes and given to the moderator in simple list form…)

Priority areas of hydrologic modeling research
Identify hydrologic regimes and representative basins of each type of regime for use in comparison studies.
Identify dominant processes for each type of hydrologic regime.
Confirm process descriptions.
Address identifiability of linked models.
Develop list of criteria for assessing model performance under various circumstances (modeling, application, and user perspectives).

Priority areas for action by the hydrologic research community
Make clear to funding agencies that model comparison requires specific money to foster cooperation.
Press agencies to make their "obscure" data available.
Press federal agencies to extend metadata standards to time series.
Press journals to adopt standards for peer review of manuscripts involving hydrologic models (description, calibration, sensitivity and uncertainty analysis, presentation of results, etc.)

Priority areas for developing modeling standards
Develop hydrologic community standards for minimally acceptable procedures for model evaluation and application. Agreed on at the meeting:
All model results should be provided with uncertainty estimates.
Develop list servers for various models (e.g., what currently exists for SWMM) and then summarize the discussions to create a "Modeler's Handbook" targeted at 4 audiences (2x2 table: model developers, model users, simulation [focus is determining relative change], forecasting [focus is the actual values]).

Original List of Questions Posed to the Four Panels
PANEL 1

Availability of integrated groundwater/surface models; use of model for period-of-record versus event modeling, and finite element versus finite difference modeling.

Role of XML.

Standard protocol to allow linkage between models data.

Have we lost sight our target – good analysis – in our desire for "cool" interfaces?

How much control should our software provide to the user via scripting, etc.?

New developments in object oriented programming including the mini-object approach being used by EPA.

How much "pretty" is too much and not useful? When does the search for user friendliness get too much priority?

What is the future for software development in terms of platforms, i.e., our major scheduling tool is written for UNIX application. What is the future for this, vs. Windows or NT platforms?

Issues of interoperability between systems.

Status of Fortran legacy code in models. Need for standardized interface files for time-series data – to promote model links

Can hydrologic models that are not spatially distributed ever be expected to provide useful information?

Level of integration/independence from proprietary GIS systems.

Strict definition of conceptual/physics based models.

Modeling "intelligent" operations.

Integrated surface and groundwater simulation.

Interested in combining atmospheric and surface models.

Degree and form of integration with other types of models (e.g., biological).

How can we meet the diverse demands for hydrologic models without proliferating numerous redundant models?

PANEL 2

Should source code of public domain software be copyrighted to protect integrity of software for public use? Executable would be in public domain.

Who (and why) is best to develop technology, create software, and maintain it?

Do federal agencies have an obligation to create publicly–accessible models and programs?

Opportunities to enhance cooperation between governmental, university, and private organizations.

Challenges faced in moving from development to use.

Can effective public/private partnerships be formed with adequate incentives on both sides to foster model improvements?

What is the best way to ensure long tern continued support of major software development, e.g. RiverWare, which is currently provided by an independent vendor? With several federal agencies now using this product, how do we keep ourselves from suddenly finding ourselves with no support if the vendor goes out of business or chooses to no longer provide support?

What is a "fair" way for sister federal agencies to share technology, including long tern modeling support, user training, "expertise" sharing, etc.?

Ideal of proprietary GUIs sharing common non-proprietary model engine.

Hydrologic model development seems to be going on simultaneously in many different arenas. Is there a simple way of keeping tract of hydrologic model development by universities or other groups?

Why are academia models not public models?

The "politics of Hydrologic models.

Is there really such a thing as public domain software?

Responsible use of hydrologic models.

Mechanisms for user/model support – what is best way an how much does it cost?

PANEL 3

Designing or updating models to be useable in other parts of the world. Providing input/output in user choice of English or metric units is the first step.

Comparison of capabilities of different models. Data needs for each model.

Model calibration procedures and user guidance. Appropriate spatial and temporal scales and issues.

The issues of scale and the adequacy of existing methods for determining watershed characteristics should be addressed. Characteristics appropriate at one scale may be grossly inadequate at other scales. The issues impact model development, roles of organizations, and appropriate use of models, in addition to model performance.

How can we ensure that users of the software are properly qualified to do so?

Who provides "certification" (aUL) for models and the appropriate applications?

Who should train users: agency, university, and/or private?

If I can't understand the model, should I use the program anyway?

Involvement of current best practices from software engineering.

How-to on moving from closed development to completely open?

Documentation standards

Does release of source code foster better model understanding or cause greater misuse due to erroneous user modifications?

I feel that each model user is responsible for knowing their own limitations, both in selecting a model for use, and interpreting the results. Just as my purchase of a STRUDL model does not make me a structural engineer, nor would it allow me to present myself as such, neither does the availability of hydrologic software make a prospective purchaser/user a hydrologic "expert". Is it necessary for the model developer to "screen" potential users for a model?

Desirability of federal agency certification.

Should certified users programs be developed?

Why do manuals on models have very little guidance for use?

How do we teach users to be better consumers and ask for better validation?

How can we get more interagency cooperation on model development, support and training? Create a Model Information Clearinghouse?

Internet resources for obtaining data and help to use models.

Parameter assignment, national parameter databases.

The advantages – disadvantages of continuous simulation versus the design-storm approach for flood frequency analysis.

User qualifications.

Panel 4

As the modular approach becomes more common how can the following be best handled: (a) model verification (not validation) and (b) experience with application, limitations, and interpretations of model outcomes give that one model can have so many alternative structures.

Interested in the tie-in between streamflow and sediment – both suspended and bedload. Important for carrying attached pollutants and toxics plus the modeling of bedload is becoming important for restoring streams, improving fish habitat, removing dams, gravel mining, etc. Some excellent data sets for bedload have been collected by the U. S. Forest Service the last several years. An excellent set of data for modeling the effect of change of discharge regime exists on the Skokomish River in Washington, which has aggraded some 4.5 feet over a 9-10 mile length as a result of diverting a major part of the flow. River profiles some 45-50 years apart exist for comparison.

Model performance criteria and evaluation procedures.

Should a federal interagency group be formed to "measure" performance?

Should software be certified?

Rigorous error analysis; calibration and verification standards.

What incentives can be offered to publish/describe honest model comparison (i.e. find out where models don't work well)?

This is a very tough issued, because many models are not directly comparable even though they may portray the idea that they are similar. Many users have their own databases to which models are linked and thus it is difficult to suggest there are "standard" datasets against which models should be checked. In selecting a particular model for purchase or use, a prospective user cannot necessarily run trial data sets to verify the answers. Choices often come down to vendor literature. User familiarity with vendor's other products, recommendations of other users, and research by the user into methods, limitations, etc. and cost of prospective models.

It would be nice to have a "rating" on a model which would show users how many resources are required to perform a certain set of calculations, i.e. for a 10 reservoir simulation model, a ten-year run by month required x Megabytes of memory and y minutes to run, However, even with this information, it is often the subtleties of how easy it is to link the model to external databases, and the complete functionality of a model that really indicates how appropriate it is for a particular application.

Effective data management

Role of EPA Environmental Technology Verification (ETV) program.

What are appropriate measures of model performance? NCASI staff has just developed a white paper on assessing model performance, which we would be willing to share with the group for discussion or during the breakout sessions.

Can all models use 3-D plotting to show results? 2002 conference – can it be with ASCE/EWRI in Albuquerque?

Calibration and Validation of hydrologic Models.

What constitutes sufficient validation from a user's perspective?

Good data for models such as rainfall and runoff should be accessible with model, or from an efficient source.

Remote sensing of channel X-sections.

Use of GIS and remote sensing to create input data and for calibration/validation.

Model calibration and guidance for same.

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SAHRA

Sustainability of semi-Arid Hydrology and Riparian Areas

"Ensuring water in a changing world"

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(4-6-01) Recharge Workshop summary and presentations have been posted

(3-22-01) **The Annual Meeting Web Page has been posted!**
view photos, posters, presentations and video

(3-14-01) Tri-University Master of Engineering in Water Resources

SPANISH

The material in this Web site is based upon work supported by SAHRA under the STC Program of the National Science Foundation, Agreement No. EAR-9876800.

- Spatial and Temporal Variability of Hydrologic Variables
- Basin-scale Water and Solute Balances
- Functioning of Riparian Systems
- Integrated Modeling of Catchment Scale Processes

- Sustainable Water Resources Management
- Technology Transfer
- Professional Development
- International Activities

- K-12 Education and Teacher Preparation
- Undergraduate Education
- Graduate Education
- Public Education and Outreach

ADMINISTRATIVE AREA (updated 1/4/01)

Modular Modeling System (MMS): *A Modeling Framework for Multidisciplinary Research and Operational Applications*

The interdisciplinary nature and increasing complexity of environmental and water-resource problems require the use of modeling approaches that can incorporate knowledge from a broad range of scientific disciplines. Selection of a model to address these problems is difficult given the large number of available models and the potentially wide range of study objectives, data constraints, and spatial and temporal scales of application. Coupled with these problems are the problems of study area characterization and parameterization once the model is selected. Guidelines for parameter estimation are normally few and the user commonly has to make decisions based on an incomplete understanding of the model developer's intent.

To address the problems of model selection, application, and analysis, a set of modular modeling tools, termed the Modular Modeling System (MMS) is being developed by the NRP Precipitation-Runoff Modeling Project. The approach being applied in developing MMS is to enable a user to selectively couple the most appropriate process algorithms from applicable models to create an "optimal" model for the desired application. Where existing algorithms are not appropriate, new algorithms can be developed and easily added to the system. This modular approach to model development and application provides a flexible method for identifying the most appropriate modeling approaches given a specific set of user needs and constraints.

MMS Information:

- MMS/Weasel Message Board
- MMS Abstract
- MMS On-Line User Manual -- Updated for software version 1.1.X (March 1998)
- MMS Installation Instructions -- Updated for software version 1.1.X (March 1998)
- MMS PRMS Module Documentation (Moved to "PRMS Sources & Documentation Page" below)
- PRMS Bibliography
- MMS Bibliography

MMS Download:

Current Stable Version - latest well tested codes. Use this version if you will not be using the new functionality of the Bleeding Edge Version.

Version: 1.1.7 *Date:* Wed Jun 21 17:41:57 MDT 2000
Bug Fixes: More work on "declpri" function in modules; also some work on sensitivity and optimization

- MMS Sources (version 1.1.7) -- Includes PRMS module library

Bleeding Edge Version - not as bad as it sounds. This version respersents the absolute latest MMS development. Some aspects of this version may not be as well tested.

Version: 1.2.0(beta)
Date: Fri Jul 14 14:18:45 MDT 2000
New Development: Seems to be compatible with the Gnu Public Licence version of Motif libraries, LessTiff (see the message board for more info).

- MMS Sources (version 1.2.0 beta) -- Includes PRMS module library

MMS Documentation:

- Postscript MMS User Manual (version 1.1.X)
- Postscript MMS Installation Instructions (version 1.1.X)

Precompiled Executables (plus README):

- Linux: Pre-compiled PRMS model (MMS version 1.1.7)
- Solaris: Pre-compiled PRMS model (MMS version 1.1.7)

MMS Utilities:

Object User Interface (OUI) -- Beta Version.

The Object User Interface (OUI) is a computer application that has been developed to provide the general framework needed to couple disparate environmental resources models and manage the necessary temporal and spatial data. Users may write model and data specific interfaces using the Java abstract *classes in the OUI library. These interfaces are dynamically loaded by OUI at run time. Through the use of these interface classes and the XML control file, OUI's data tree and map based graphical user interface are highly configurable for most all applications. The OUI user's manual provides installation instructions, a detailed discussion of system concepts, a working example with complete data sets, and specifications for interface development and application using the OUI graphical user interface.*

I'm looking for a few good reviewers!! OUI cannot be offically released until the User's Manual receives USGS approval. That means that I need a few reviews of the User's Manual. If you want to do this, please email Steve Markstrom (markstro@usgs.gov).

Until then . . .

Please be advised that the Object User Interface (OUI) software and User's Manual is preliminary in nature and presented prior to final review and approval by the Director of the USGS. This information is provided with the understanding that it is not guaranteed to be correct or complete and conclusions drawn from such information are the sole responsibility of the user.

- Draft online OUI User's Manual
- Draft PostScript OUI User's Manual
- OUI Beta Distribution w/example data for Gunnison River Project

Time Series Data Grabber - connects to web sites and downloads time series data into an MMS intput file.

- Time Series Data Grabber README
- Time Series Data Grabber tar ball

USGS Module Library Pages:

- PRMS Documentation & Sources Page
- TOPMODEL Sources & Documentation (coming soon)
- DAFLOW Sources & Documentation (coming soon)

Status:

In order to provide a better response to MMS and GIS Weasel users, we have created the MMS/Weasel Message Board. *All bug reports, comments, and questions should be entered there.*

- New MMS Features
- Add Me to the MMS Mailing List (Include the word "subscribe" in body of letter)
- Your Comments/Bug Reports

- Undocumented MMS Features
- Known MMS Bugs
- Frequently Asked Questions
- Proposed MMS Enhancements

Contacts:

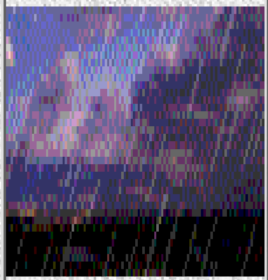
- George Leavesley (Precipitation Runoff Project Chief)
  Phone: 303-236-5026
  email: george@usgs.gov

- Steve Markstrom (MMS Development & Support)
  Phone: 303-236-3330
  email: markstro@usgs.gov

- Roland Viger (GIS Weasel Development & Support)
  Phone: 303-236-5030
  email: rviger@usgs.gov

[USGS Home Page] [NRP Home Page] [Help Page] [GIS Weasel Home Page]

Steve Markstrom, <markstro@usgs.gov>
Last modified: Fri Sep 8 08:36:17 MDT 2000



The GIS Weasel!!

An Interface for The Treatment of Spatial Information in Modeling

Information:

[Abstract: The GIS Weasel]

[The GIS Weasel Installation Instructions]

[GIS Weasel Problem Sets] UPDATE

[The GIS Weasel and Data] a discussion of elevation data, the GIS Weasel *data_bin*, and Internet sources of data

[The GIS Weasel On-Line User Manual] (Draft actively under construction!)

Software:

The GIS Weasel uses ArcInfo under both Unix and Windows-NT!!

Beta Version: 0.3.66 UPDATE *Date:* Wed Feb 14 11:20:45 MST 2001

[The GIS Weasel 7.5MB (.tar.gz)] (decompresses to 20MB)

Other Information:

[Weasel/MMS Message Board] NEW

[Add Me to the GIS Weasel Mailing List] (Include "subscribe" in body of letter)

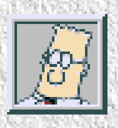
[Article: The GIS Weasel - An Interface for the Treatment of Spatial Information...]

- Article: A Modular Approach to Integrating Environmental Modeling and GIS
- Graphics: 2 posters (11x45", 35x47")

- Frequently Asked Questions

- Your Comments/Bug Reports

[USGS Home Page] [NRP Home Page] [Help Page] [MMS Home Page] [WARSMP Home Page]

Roland Viger, <rviger@usgs.gov> 

WaRSMP

Watershed and River System Management Program

A cooperative effort between Department of the Interior Agencies

- **Introduction**
- **RiverWare**
- **Modular Modeling System**
- **The GIS Weasel**
- **Hydrologic Data Base**
- **Management Applications**
- **Cooperators**
- **External Technical Review**
- **Bulletin board** of meeting notes/reports.

Address: http://wwwbrr.cr.usgs.gov/warsmp

Page maintained by:
Roland Viger (USGS)
Mark A. Treviño (USBR)

Last Modified:
Sunday, 28-Feb-1999 12:21:08 MST

WaRSMP

Watershed and River System Management Program

A cooperative effort between Department of the Interior Agencies

Introduction

The Watershed and River System management Program is sponsored by the Bureau of Reclamation's Science and Technology Research Program and the U.S. Geological Survey's Water Resource Division. This program provides a data centered framework for water resources decision making. Today's complex water resources management issues require flexible, comprehensive decision support tools that display timely information to water managers. River systems operate under laws, compacts, treaties and court decrees, while meeting increasing demands that compete for limited fresh water supplies.

This interagency program supports development and application of decision support systems that will assist the resource manager to achieve an equitable balance among the following uses:

- Municipal
- Fish and Wildlife
- Agricultural
- Recreational
- Hydropower
- Water Quality

RiverWare

RiverWare is a general purpose, interactive model building tool used to develop water distribution models for:

- *short-term operations and scheduling*
- *mid-term operations and planning*
- *long-term policy and planning*

RiverWare is an object-oriented reservoir and river system modeling framework developed by the Center for Advanced Decision Support for Water and Environmental Systems (CADSWES) at the University of Colorado with funding provided by The U.S. Bureau of Reclamation, and the Tennessee Valley Authority (TVA).

RiverWare Fact Sheet is available as well as some **Screen Shots**

MMS - Modular Modeling System

MMS is a model building framework to simulate a wide range of interdisciplinary environmental and water resource physical processes. MMS was initially developed colloboratively by CADSWES and the U.S. Geological Survey (USGS). Enhancements are presently being made and supported by the USGS. Components of MMS include:

- Pre-processors to access and prepare data
- A library of models and modules to simulate hydrologic and ecosystem processes

- Post-processors to display and analyze model results.

Basin models may be run using meteorological historic data or input from weather and climate models. Resulting simulated streamflow may be used directly by river basin managers or to subsequently simulate alternative operating scenarios.

Visit the **MMS Web Page**	View the **MMS Overview Poster**

The GIS Weasel!! -

An Interface for the Treatment of Spatial Information in Modeling

The GIS Weasel is an Arc/INFO based application for defining areas of modeling interest, analyzing attributes of these areas, and deriving measures for these attributes. The GIS Weasel has been developed by the U.S. Geological Survey (USGS). Enhancements are presently being made and supported by the USGS. Functions of The GIS Weasel include:

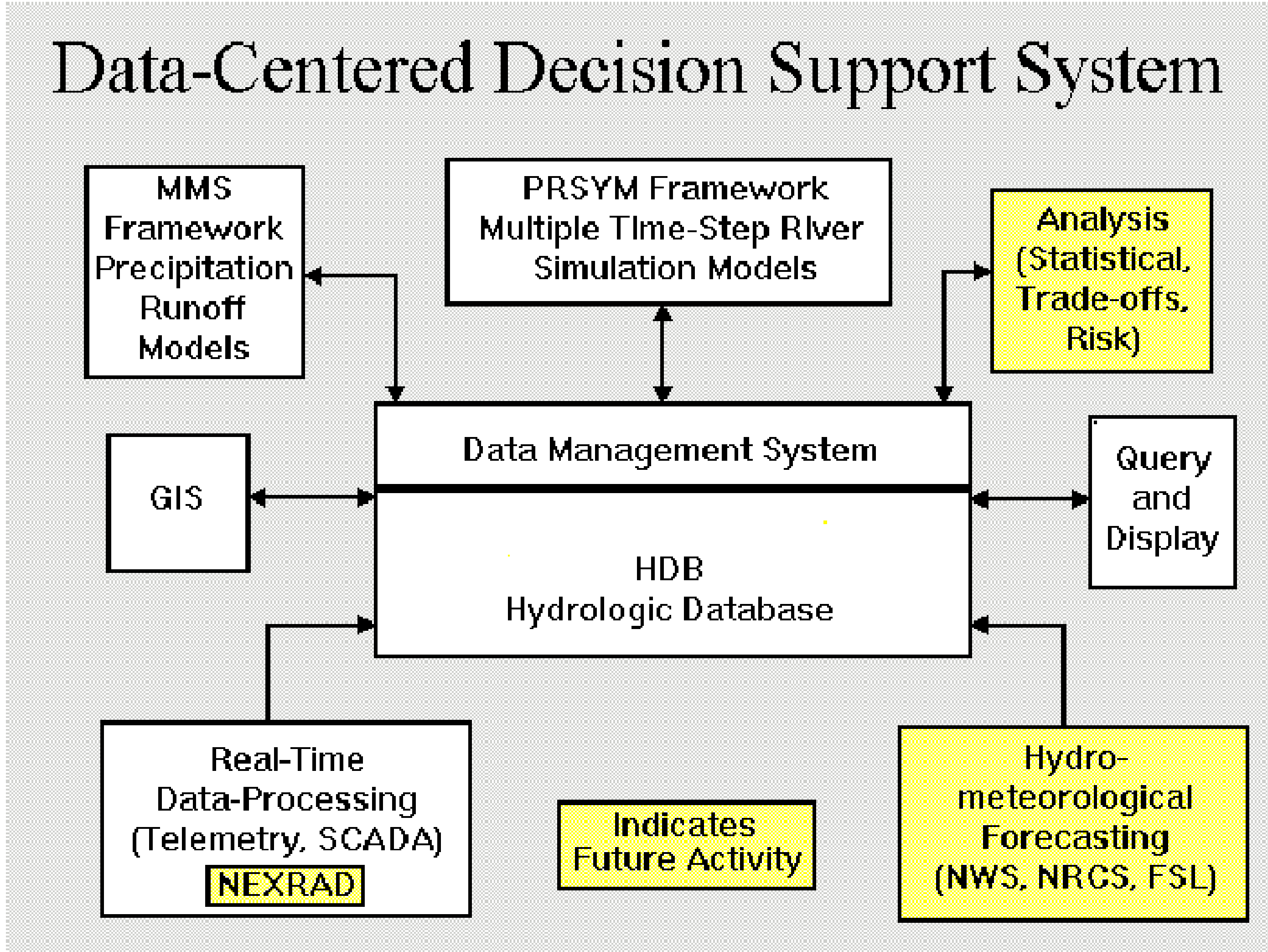
- Delineation of watersheds
- Extraction of drainage networks
- Definition of sub-watersheds as units of model response (MRUs)
- Characterization and modification of MRUs
- Parameterization of MRU attributes for input to models

Visit the **GIS Weasel Web Page**

HDB - Hydrologic Data Base

The HDB is a relational database which includes streamflow, reservoir operations, SNOTEL/snowpack, weather, and other data. Data are continually updated automatically from telemetry, SCADA, and other real-time systems. Ultimately, it will include water accounting, water rights information, data and NEXRAD precipitation estimates. HDB is the key to successful desicion making with rapid access to timely information.

The ability to link other modules to the database (including the modeling components) provides a consistent view of the historical, current, and future predictions. Other modules make it easy to query, analyze, and display this information to the water resource managers.



Water Resources Management Applications

Operational analysis and runoff prediction tools support:

- improved precipitation and snowmelt forecasting to allow more effective and efficient river basin management
- determination of *"available water"* in the river basin system
- prediction of short term (12 to 48 hour) supply and flood threats
- estimation of long term (1 to 12 month) probable supplies (10, 50, 90% exceedence) for Annual Operation Plans
- simulation of long term (10 to 85 year) river basin management scenarios (using historic and stochastic streamflow data)
- water scheduling for:
    - Irrigation Delivery
    - Hydroelectric Power

- Instream Flows
- Water Quality

[Yakima River Basin, Washington](#)

[San Juan River Basin, Colorado](#)

Contributing, Participating and Cooperating Agencies

- **U.S. Bureau of Reclamation**
- **U.S. Geological Survey**
- **Tennessee Valley Authority**
- **Western Area Power Administration**
- **National Oceanic and Atmospheric Administration**

External Technical Review

An ad-hoc User Group reviews the models and products generated by RiverWare and MMS. Interested parties are invited to join the User Group.

For information on joining the User Group or general information on this program please contact any of the WARSMP Sponsors

layer hidden off the screen

Quick access

Select Group of Users ...

Other DHI web sites

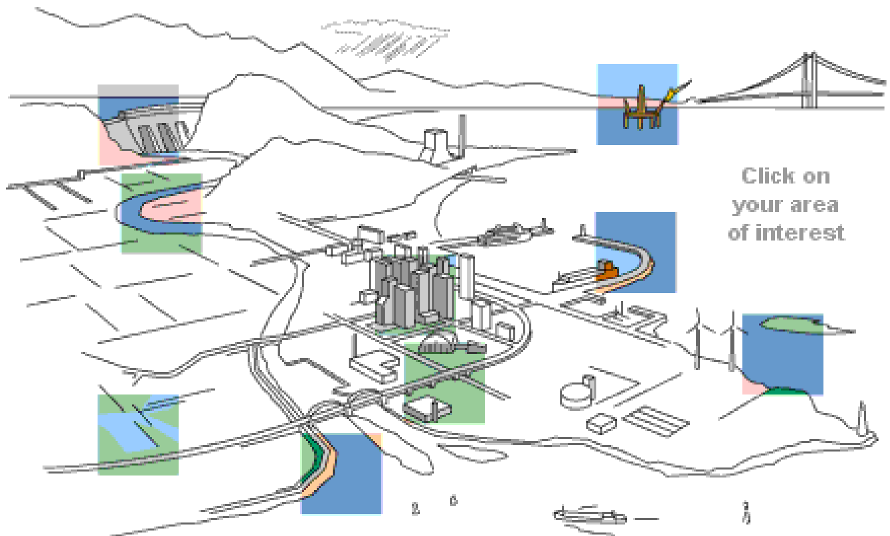
Select Website ...

&

DHI Water & Environment
...a merger between
Danish Hydraulic Institute and
VKI - Institute for the Water Environment

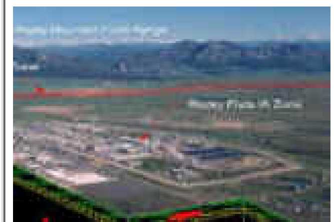
DHI Water & Environment

A leading provider of consultancy and technology



DHI Water & Environment, Agern Allé 11, DK-2970 Hørsholm, Denmark
Tel: +45 4516 9200, Fax: +45 4516 9292, dhi@dhi.dk

News



MIKE SHE groundwater model selected as best management tool in the US (3/5-2001)

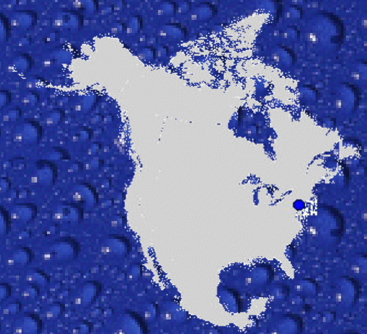
DHI representative in India (26/4-2001

More news...

DHI and the EU Water Framework Directive

DHI Software

Remember to register for the 4th DHI Software Conference



DHI Inc. - Phil., PA
Eight Neshaminy Interplex, Suite 219
Trevose, PA 19053
Tel: 215-244-5344
Fax: 215-244-9977
mail:dhi@dhigroup.com

Directions to DHI Inc.:
Philadelphia Map
Neshaminy Map

DHI Inc. - Tampa, FL
907 South Rome Avenue
Tampa, FL 33606
Tel: 813-254-9427
Cell: 813-431-4959
Fax: 813-254-7708

DHI Inc.

DHI
WATER & ENVIRONMENT

DHI Inc. is the North American subsidiary of DHI - Water & Environment.   DHI Inc. offers advanced integrated modeling tools and consulting services for :

- Flooding - analysis, setup of operational flood forecast systems
- River environment and morphology
- Water resources and hydrology – analysis and planning
- Urban drainage and pollution management

DHI News

Workshops for DHI Software!

MIKE 11 - Canada

MIKE SWMM

Announcing DHI's 2001 Software Conference

MOUSE LTS for Long-Term Simulations

HOT **FEMA Approves MIKE 11 for NFIP Use**

Two new mailing lists are now available for DHI Software Users.

FREE

All our animations and web pages are available on a free CD-ROM.

- Coastal environment and coastal morphology
- Scour and sedimentation around structures and sediment spills during dredging
- Ports and harbors, offshore structures and pipelines

DHI is dedicated to maintaining our technological excellence in the future – and we are dedicated to sharing our know-how with our growing global network of partners, users and clients.

DHI Software

- About DHI Software
- Request Information
- Support
- Software Ordering
- Training

Modeling the World of Water

- More News
- 4th DHI Software Conference
- Software Mailing Lists
- Request a Free CD with Animations
- DHI Network Guide

DHI WATER & ENVIRONMENT

Welcome to the web site for DHI Software!

- The leading software products for modeling of water since 1985
- Thousands of users in 70 countries
- Covers water from source to tap, from rainfall to the ocean
- Technical support on six continents

CLICK on a product name above - or use the navigation bar to the left

MIKE BASIN MIKE BASIN
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MIKE SWMM MIKE SWMM MOUSE MOUSE LITPACK LITPACK MIKE 21 MIKE 21

USGS
science for a changing world

National Elevation Dataset

The USGS National Elevation Dataset (NED) has been developed by merging the highest-resolution, best-quality elevation data available across the United States into a seamless raster format. NED is the result of the maturation of the USGS effort to provide 1:24,000-scale Digital Elevation Model (DEM) data for the conterminous US and 1:63,360-scale DEM data for Alaska. The NED Store offers seamless data for sale, by user-defined area, in a variety of formats. Our Samples link has free NED data for testing and representative applications.

Follow the About link for details on the processing methods used to create NED, DEM standards, and data accuracy information. The Data Source Index included in that section provides a visual index into the properties of the individual source datasets used in NED. Since NED is a living dataset, frequently updated to incorporate "best available" DEM data, users are encouraged to check the Data Source Index for changes in their area of interest. Additional information may be found on our FAQ page or you may contact us by email.

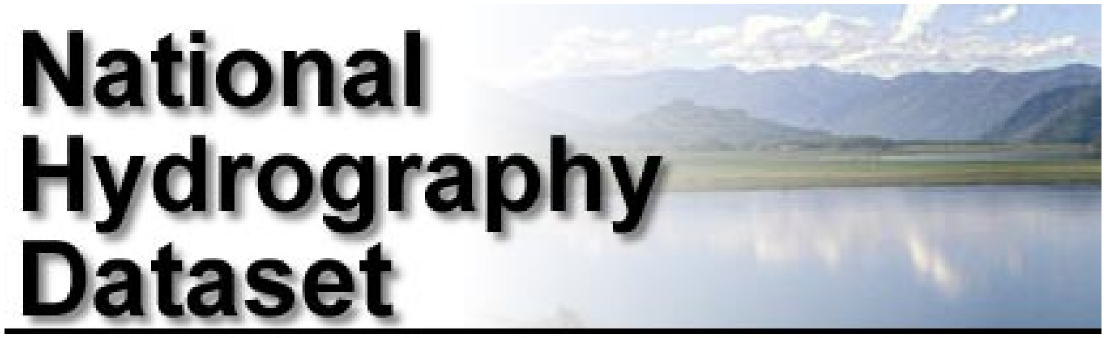
U. S. Department of the Interior
U. S. Geological Survey
National Mapping Division
EROS Data Center
Comments and Suggestions
Last modified:
http://edcnts12.cr.usgs.gov/ned

USGS science for a changing world

EPA United States Environmental Protection Agency

text version

- NHD Home
- Technical References
- Data
- Tools
- Application Demo
- Tutorial Series
- Technical Support
- Maintenance



The National Hydrography Dataset (NHD) is a comprehensive set of digital spatial data that contains information about surface water features such as lakes, ponds, streams, rivers, springs and wells. Within the NHD, surface water features are combined to form "reaches," which provide the framework for linking water-related data to the NHD surface water drainage network. These linkages enable the analysis and display of these water-related data in upstream and downstream order.

The NHD is based upon the content of USGS Digital Line Graph (DLG) hydrography data integrated with reach-related information from the EPA Reach File Version 3 (RF3). The NHD supersedes DLG and RF3 by incorporating them, not by replacing them. Users of DLG or RF3 will find the National Hydrography Dataset both familiar and greatly expanded and refined.

While initially based on 1:100,000-scale data, the NHD is designed to incorporate and encourage the development of higher resolution data required by many users.

NHD News

Due to a load error, NHD data in the database could have been corrupted. We are recommending that any datasets downloaded from March 26 to April 11, 2001 should be downloaded again. (4/19/01)

Slides and Videos from the NHD Applications Symposium (2/28/01)

NHD News Archive

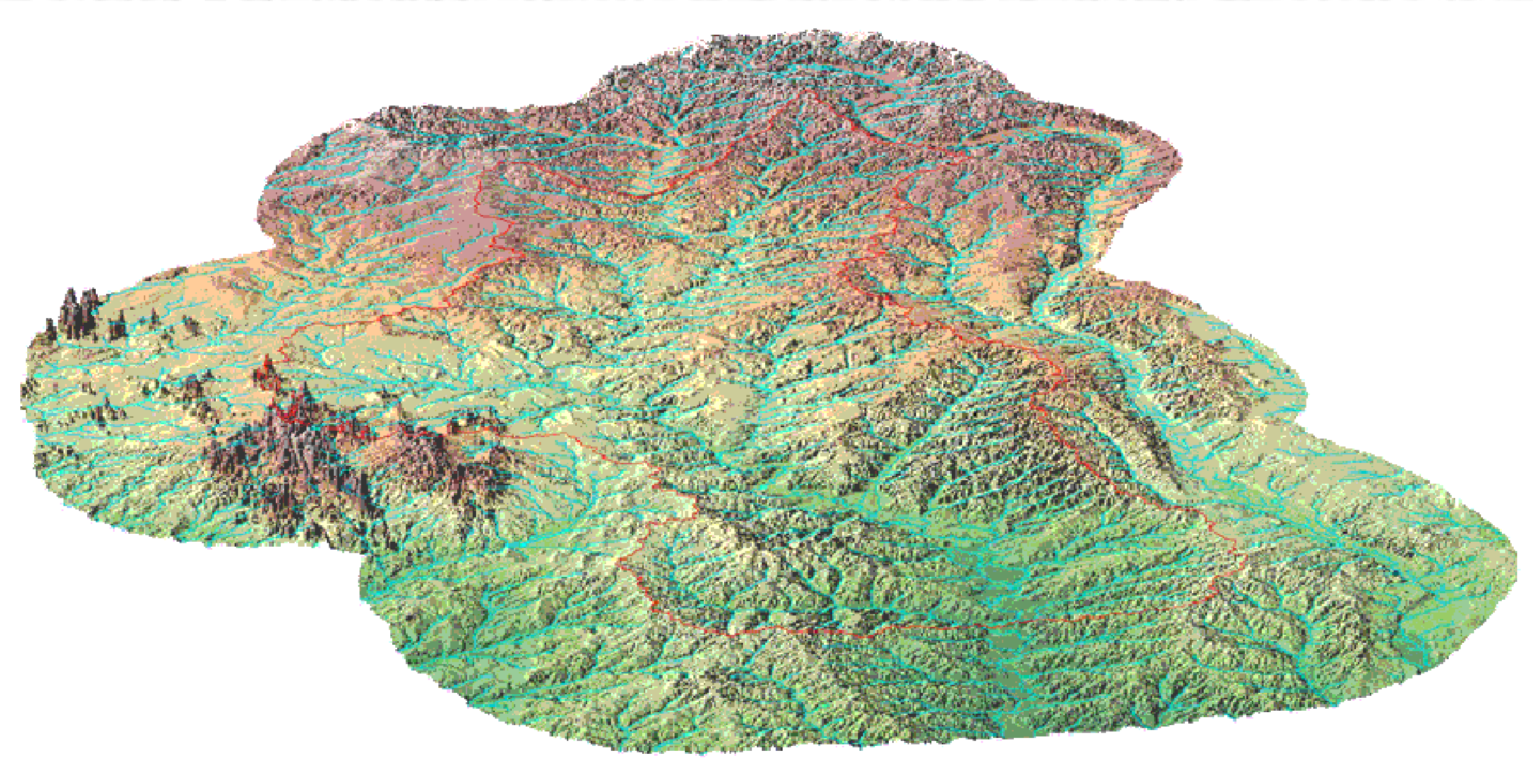
Search USGS | USGS | EPA | FGDC

U.S. Department of the Interior
U.S. Geological Survey
URL: *http://nhd.usgs.gov/index.html*
Last modified: Wednesday, 02-May-2001 08:11:21 CDT
Maintainer: nhd@usgs.gov
USGS Privacy Statement

FirstGov Your First Click to the U.S. Government science for a changing world

National Elevation Dataset - Hydrologic Derivatives

Home About Data Samples FAQ Contact Us



The National Elevation Dataset-Hydrologic Derivatives (NED-H) is an interagency effort with its goal the development of a hydrologically correct version of the National Elevation Dataset (NED) and systematic derivation of standard hydrologic derivatives. The quality and wall-to-wall coverage of the high resolution digital elevation data, the development of the National Hydrography Dataset (NHD) and advances in GIS application of terrain modeling have made possible the development of these derivative data layers.

Follow the About link above for details on the dataset, data accuracy assessment and development methodology. Our Samples link has free NED-H data for testing and representative applications and links to on-going NED-H applications. The data will, ultimately, be delivered through the Seamless Data Access and Delivery Project at the EROS Data Center. In the near future, the Data link will provide access to the NED-H data along with other seamless geospatial datasets.

Additional information may be found on our FAQ page or you may contact us by email.

Check out the Summary from our Collaborators Meeting held January 25-27,2000 at the EROS

Data Center.

NWS Blind Pass Status Graphic is available here

National Elevation Dataset - Hydrologic Derivatives

Please read this general **Disclaimer**

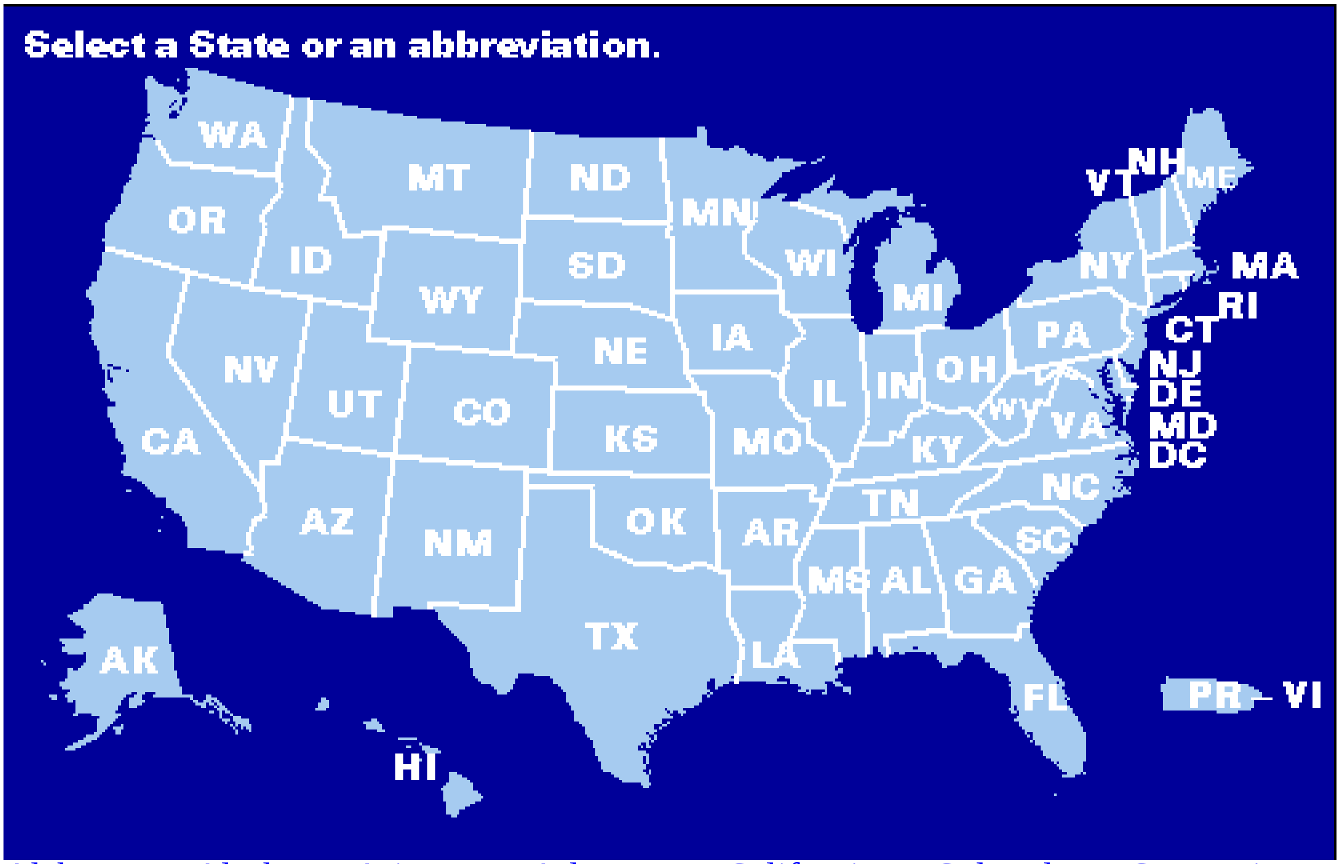
U. S. Department of the Interior
U. S. Geological Survey
National Mapping Division
EROS Data Center

Comments and Suggestions

Last modified: Friday, December 8, 2000
http://edcnts12.cr.usgs.gov/ned-h

United States NWIS-W Data Retrieval

Select a state from the map below, or by name from the list. This will bring you to that state's NWIS-W page, which has data and summaries for stations in that state. Or, use the links below the map to perform nationwide searches.



Alabama Alaska Arizona Arkansas California Colorado Connecticut Delaware District of Columbia Florida Georgia Hawaii Idaho Illinois Indiana Iowa Kansas Kentucky Louisiana Maine Maryland Massachusetts Michigan Minnesota Mississippi Missouri Montana Nebraska Nevada New Hampshire New Jersey New Mexico New York North Carolina North Dakota Ohio Oklahoma Oregon Pennsylvania Puerto Rico Rhode Island South Carolina South Dakota Tennessee Texas United States Utah Vermont Virginia Washington West Virginia Wisconsin Wyoming American Samoa Canal Zone Canton and Enderbury Islands Guam Johnson Atoll Midway Islands Ryukyu Islands, Southern Swan Islands Trust Territories of the Pacific Islands U.S. Miscellaneous Caribbean Islands U.S. Miscellaneous Pacific Islands Virgin Islands Wake Island Mexico New Brunswick Quebec Ontario Manitoba Saskathewan Alberta British Columbia Yukon Canada

Locate Stations of Interest

- You may search the list of United States Gaging Stations
- You may locate station(s) of interest using
  - a list of counties in United States
  - a list of basins in United States

Go to the United States Water Resources page

??Get help with the terms used on these pages

Comments and questions are welcome! Please visit our feedback page or email h2oteam@usgs.gov.

This page was created in real time by the NWIS-W package: (NWIS-W: 3.1 ; nwis-w: 3.1)

Land Cover Characterization Program

Overview

Global Land Cover Characterization

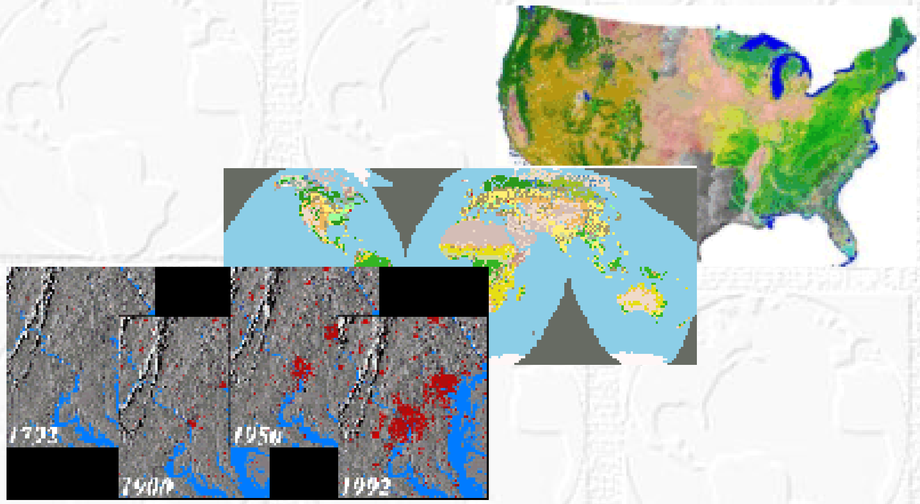
National Land Cover Characterization

Urban Dynamics

Land Cover Trends

Land Cover Applications Center

Applications & Other Agencies



NLCD Downloadable Image Database!
New NLCD Land Cover Statistics!
Land Cover Data Links Updated!

EDC Home Page	LCCP Home Page	Overview	Global	National	Urban Dynamics	Trends	Applications	Links	Contact Us

U.S. Department of the Interior
U.S. Geological Survey
Please read this general **Disclaimer**
URL: http://edc.usgs.gov/programs/lccp/index.html
Maintainer: edcweb@usgs.gov
Last Update: Thursday, May 03, 2001.
USGS Privacy Statement

GIS HYDRO 2000

Prepared by

Center for Research in Water Resources, University of Texas at Austin

in collaboration with the Consortium for GIS in Water Resources

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Introduction	Classroom	Library

National Hydrography Dataset

ArcGIS Hydro Data Model

ArcGIS Hydro Data Model Documentation

National Hydrography Dataset Application Symposium
December 11-14, 2000
Austin, Texas

The first-ever NHD Application Symposium was held on December 11-14, 2000, at the University of Texas JJ Pickle Research Campus in Austin, Texas. The Symposium served as a forum for the presentation and discussion of applications using the National Hydrography Dataset (NHD) and several other closely associated national datasets, the National Elevation Dataset (NED), the NED hydrologic derivatives (NED-H) and the National Watershed Boundary Dataset (NWBD).

The Symposium was sponsored by:

- U.S. Geological Survey
- U.S. Environmental Protection Agency
- Center for Research in Water Resources at the University of Texas at Austin

Follow the links from the Symposium agenda below to find the abstract, slides (.ppt) and streaming video (.asx) for each presentation. The Microsoft Windows Media Viewer will play the streaming video. Thanks for your interest!

Monday, December 11th

1:00 - 5:30 PM - Plenary Session

1:00 - 1:15 PM - Welcome and Introductory Remarks

1:15 - 2:45 PM - Keynote Speakers

- Karen Siderelis, U.S. Geological Survey / Geographic Information Officer
- Robert Hirsch, U.S. Geological Survey / Associate Director for Water
- Andrew Battin, U.S. Environmental Protection Agency / Senior Information Resources Management Officer, Office of Water
- Barbara Ryan, U.S. Geological Survey / Associate Director for Geography

2:45 - 3:00 PM - Break

3:00 - 5:00 PM - Status and Integration of the National Datasets

- National Hydrography Dataset (NHD)

  Keven Roth, U.S. Geological Survey
- National Elevation Dataset (NED)

  Sue Greenlee, U.S. Geological Survey
- National Elevation Dataset - Hydrologic Derivatives (NED-H)

  Kris Verdin, U.S. Geological Survey
- National Watershed Boundary Dataset (NWBD)

  Alan Rea, U.S. Geological Survey

5:00 - 5:30 PM - Geo-enabled Water Resources Modeling: The Next Generation

- Dr. David Maidment, University of Texas at Austin / Director, Center for Research in Water Resources

Tuesday, December 12th

8:00 AM - 12:15 PM - Application Session A

- Introductory Remarks

  Thomas G. Dewald, U.S. Environmental Protection Agency
- Watershed Assessment Tracking Environmental Results System (WATERS)

  Thomas O. Dabolt, U.S. Environmental Protection Agency
- Georeferencing Water Quality Information to the NHD

  Anne Marie Miller and Kimberly Sparks, Research Triangle Institute
- Implementing NHD Spatial Data in the U.S. Forest Service NRIS Water Application

  Brian Sanborn, U.S. Forest Service
- High Resolution NHD Partnerships and Lessons Learned

  Keven Roth, U.S. Geological Survey

10:00 - 10:15 AM - Break

- NHD Flow Volume and Velocity Estimation

  Greg Schwarz, U.S. Geological Survey
- NHD Stream Order Tool Possibilities

  Timothy Bondelid, Research Triangle Institute
- The Reach Address Database (RAD) - An Application-Ready NHD Implementation

  Steve Andrews, INDUS Corporation
- Seamless Access and Delivery for the USGS's National Elevation Dataset

  Dave Greenlee, U.S. Geological Survey

12:15 - 1: 45 PM - Lunch

Posters and Demonstrations including:

- 12:45 - 1:15 PM - Web-based NHD Update Concepts

  Erica Boghici and Marcy Berbrick, Texas Water Development Board
- 1:15 - 1:45 PM - The GIS Weasel

  R. J. Viger, U.S. Geological Survey

1:45 - 3:15 PM - ArcGIS Hydro Data Model Session (Consortium for GIS in Water Resources)

- ArcGIS Geodatabase Models

  Steve Grise, Environmental Systems Research Institute
- Integrating the National Hydro Datasets

Dr. David Maidment, University of Texas at Austin

3:15 PM - University of Texas at Austin Campus closed unexpectedly due to an ice storm! The Symposium resumed the following morning, Wednesday, December 13th, at 10:30 AM, once the Campus had re-opened.

Wednesday, December 13th

10:30 - 11:30 AM - ArcGIS Hydro Data Model Session (continued)

- The ArcGIS Hydro Data Model

  Dr. David Maidment, University of Texas at Austin

11:30 AM - 12:45 PM - Application Session B

- NHD and National Water Information System (NWIS) Web Application

  Tim Whiteaker, University of Texas at Austin
- Map-making Using the NHD

  Bill Wheaton, Research Triangle Institute
- Introducing the NHD ArcView Tool Kit

  Jen Hill, Horizon Systems Corporation
- NHD Names Update Tool

  Keven Roth, U.S. Geological Survey

12:45 - 1: 45 PM - Lunch

Posters and Demonstrations including:

- 1:05 - 1:45 PM - Basin Characteristics Panel Discussion

  Alan Rea, U.S. Geological Survey

1:45 PM - 5:25 PM - Application Session C

- Implementing the 1:24,000-scale NHD Model in Georgia

  David Holcomb and Eric McRae, University of Georgia
- Minnesota Hydrography Activities

  Mark Olsen, Minnesota Pollution Control Agency
- Use of the National Hydrography Dataset in BASINS 3.0

  Henry Manguerra, Tetra Tech Inc.
- A Prototype for a USGS National Rivers Information Center

  Kernell G. Ries III, U.S. Geological Survey
- Massachusetts GIS-Watershed Tools

  Peter Steeves, U.S. Geological Survey

3:40 - 3:55 PM - Break

- STORET Water Quality Database and the NHD

  Thomas O. Dabolt, U.S. Environmental Protection Agency
- Developing a National Database of Watersheds and Watershed Characteristics for Community Water Systems that Withdraw from Surface Water

  Michael E. Wieczorek, U.S. Geological Survey
- Criticality of Point Features in NHD-Based Hydrologic Modeling

  Budhendra Bhaduri, Oak Ridge National Laboratory
- ESRI's Water Resources Extension Tools

  Dean Djokic, Environmental Systems Research Institute

5:25 - 5:45 PM - User Forum (Questions and Answers) and Closing Remarks

Thursday, December 14th

8:30-5:00 PM - Training Sessions and Seminars

- Introduction to the NHD Training (8:30 AM - Noon & 1:30 - 5:00 PM)
- Reach Indexing Tool (RIT) Training (8:30 AM - Noon & 1:30 - 5:00 PM)
- Moving to High Resolution NHD Seminar (8:30 AM - Noon)
- NED-H Stage 2 Seminar (1:30-4:00 PM)

Abstracts for the National Hydrography Dataset Application Symposium
December 11-14, 2000
Austin, Texas

Monday Afternoon, December 11, 2000

- **Keynote Speakers:**

Karen Siderelis [no slides] [video]
Geographic Information Officer
U.S. Geological Survey
Reston, VA
ksiderelis@usgs.gov

Robert Hirsch [slides] [video]
Associate Director for Water
U.S. Geological Survey
Reston, VA
rhirsch@usgs.gov

Andrew Battin [slides] [video]
Senior Information Resources Management Officer, Office of Water
U.S. Environmental Protection Agency
Washington, DC

Battin.Andrew@epa.gov

Barbara Ryan [slides] [video]
Associate Director for Geography
U.S. Geological Survey
Reston, VA
bjryan@usgs.gov

- **National Hydrography Dataset (NHD)** [slides] [video]

Keven Roth
U.S. Geological Survey
Reston, VA
kroth@usgs.gov

The National Hydrography Dataset (NHD) is a geographic database that interconnects and uniquely identifies the stream segments or "reaches" that comprise the nation's surface water drainage system. It is based initially upon the content of the U.S. Geological Survey 1:100,000-scale Digital Line Graph (DLG) hydrography data integrated with reach-related information from the U.S. Environmental Protection Agency Reach File Version 3.0 (RF3). More specifically, it contains reach codes for networked features and isolated lakes, flow direction, names, stream level, and centerline representations for areal water bodies.

The NHD provides a national framework for assigning reach addresses to water-related entities, such as industrial dischargers, drinking water supplies, fish habitat areas, wild and scenic rivers. Reach addresses establish the locations of these entities relative to one another within the NHD surface water drainage network in a manner similar to street addresses. Once linked to the NHD by their reach addresses, the upstream/downstream relationships of these water-related entities and any associated information about them can be analyzed using software tools ranging from spreadsheets to Geographic Information Systems (GIS). GIS can also be used to combine NHD-based network analysis with other data layers, such as soils, land use and population, to help better understand and display their respective affects upon one another. Furthermore, since the NHD provides a nationally consistent framework for addressing and analysis, water-related information linked to reach addresses by one organization (national, state, local) can be shared with other organizations and easily integrated into many different types of applications to the benefit of all.

The National Hydrography Dataset is designed to provide comprehensive coverage of hydrologic data for the US. While initially based on 1:100,000-scale data, the NHD is designed to incorporate -- and encourage the development of -- higher-resolution data required by many users. It will facilitate the improved integration of water-related data in support of the application requirements of a growing national user community and will enable shared maintenance and enhancement.

For more information on the National Hydrography Dataset, see http://nhd.usgs.gov.

- **National Elevation Dataset (NED)** [slides] [video]

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The National Elevation Dataset (NED) has been developed by merging the highest-resolution, best-quality elevation data available across the United States. NED is the result of the maturation of the USGS effort to provide 1:24,000-scale Digital Elevation Model (DEM) data for the conterminous US and 1:63,360-scale DEM data for Alaska. It has a resolution of one arc-second (approximately 30 meters) for the conterminous United States, Hawaii, and Puerto Rico and a resolution of two arc-seconds for Alaska. NED is designed to provide National elevation data in a seamless raster format with a consistent datum, elevation unit, and projection. Data corrections were made in the NED assembly process to minimize artifacts, perform edge matching, and fill sliver areas of missing data. These processing steps ensure that NED has no void areas and artificial discontinuities have been minimized. As higher-resolution or higher-quality data become available, the NED is periodically updated to incorporate best-available coverage. Also, as more data become available at a finer resolution than NED, the feasibility of developing a finer resolution NED will be investigated.

For more information on the National Elevation Dataset, see http://edcnts12.cr.usgs.gov/ned.

- **National Elevation Dataset - Hydrologic Derivatives (NED-H)** [slides] [video]

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The National Elevation Dataset - Hydrologic Derivatives (NED-H) is intended to develop a hydrologically correct version of the NED and systematic derivation of standard hydrologic derivatives. The recent completion of the NED and the NHD combined with advances in GIS application of terrain modeling have made possible the development of these topographically derived hydrologic data layers at a scale of 1:24,000. Some of the benefits of a nation-wide development of hydrologic derivatives are:

- NED-H derived drainage basin boundaries can be used to provide high-resolution boundaries for the new National Watershed Boundaries Dataset (NWBD). The NWBD strives to identify the "best-available" watershed boundaries on a national level.
- NED-H will provide the capability of developing drainage basin boundaries above any point within the U.S. All locations downstream from any point in the U.S. can also be readily determined using the NED-H derivative data layers.
- NED-H will serve to integrate the NED and the NHD, with the NHD reach code providing the bridge between the rich cartographic feature content of the NHD and the rich topographic content of the NED. Enhancements to both datasets are expected as quality control procedures used in the development of the NED-H provide feedback to both NED and NHD. The NHD will be further enhanced by consistency with the NED-H. Elevation-derived streamline and basin parameters can be transferred onto the NHD following conflation with the NED-H. This will provide valuable attributes useful in model parameterization.

For more information on the National Elevation Dataset - Hydrologic Derivatives, see http://edcnts12.cr.usgs.gov/ned-h .

- **National Watershed Boundary Dataset (NWBD)** [slides] [video]

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Federal agencies coordinating spatial water data have identified the development of a National Watershed Boundaries Data Set as a top priority for inclusion in the National Spatial Data Infrastructure (NSDI).

The proposed NSDI Watershed Boundaries Data Set will have the following key characteristics:

- Nationally consistent digital data set
- Nested subdivisions of established Cataloging Units
- 5-15 Watersheds per Cataloging Unit
- Boundaries based on 1:24,000-scale topographic maps
- Hydrologically based watersheds, not political divisions
- 10-digit Hydrologic Unit Codes
- Formally established watershed names
- Attribute information to identify all upstream and downstream units

Where watershed boundaries have not already been mapped using appropriate criteria, new watershed boundaries will be developed using a semi-automated procedure based on elevation data from the National Elevation Dataset. The boundaries will be checked and edited using 1:24,000-scale Digital Raster Graphics.

The National Watershed Boundaries Data Set, the National Elevation Dataset, and National Hydrography Dataset inherently are related. Early maintenance efforts will seek to identify inconsistencies between these three data sets and use those inconsistencies to help improve the quality of each national data set.

For more information on the National Watershed Boundary Dataset, see http://www.ftw.nrcs.usda.gov/huc_data.html

- **Geo-enabled Water Resources Modeling: The Next Generation** [slides] [video]

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A review is made of current trends in geospatial water resources modeling, which give a view on emerging technologies expected to become more widespread in coming years. Two themes are emphasized:

- Building water resources models within a GIS framework – integrating environmental and process descriptions of the landscape
- Stronger integration of geospatial and temporal data – the development of dynamic mapping

Data structures being used for the ArcGIS Hydro data model are used to explain how the next generation of GIS technology can support water resource process represetations as well as geospatial and temporal water resources data. An example of data collection from the Klamath River in Oregon and California is used to show how new technologies of water resources measurement can be combined with GIS and modeling to create precise descriptions of stream channels and water movement in them.

Tuesday Morning, December 12, 2000

- **Introductory Remarks** [no slides] [video]

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- **Watershed Assessment Tracking Environmental Results System (WATERS)** [slides] [video]

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The EPA Office of Water is currently developing a data system to integrate water quality monitoring data, state reported water quality assessments, the status of total maximum daily loads (TMDLs) in conjunction with any associated legal obligations, and the environmental results associated with Clean Water Act Section 319 funding. The new system, the Watershed Assessment Tracking Environmental Results System (WATERS), will integrate program databases using the National Hydrography Dataset (NHD) as the spatial framework. Initially, this integration coupled with an EPA-internal Web-based user interface will allow EPA Office of Water managers and staff to ask and answer numerous programmatic questions in support of assessment and monitoring activities. Ultimately, information within WATERS is to be accessible to the public from a Web-based geographic query and reporting application.

- **Georeferencing Water Quality Information to the National Hydrography Dataset** [slides] [video]

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This paper describes the application of innovative GIS techniques to georeference or link water quality related information for the country to the National Hydrography Dataset (NHD). One major effort by the U.S. Environmental Protection Agency has resulted in the georeferencing of over 18,000 impaired waterbodies listed by the states in 1998 under Section 303(d) of the Clean Water Act. Prior to this initiative, many of the impaired waters listed by the 50 states had never been mapped and could not be displayed on demand or analyzed spatially. Knowing the exact locations and attributes of these listed waters is crucial to developing Total Maximum Daily Loads (TMDLs) and to assessing water quality improvement after TMDLs are implemented. To achieve national consistency and efficiency, the technical approach involved the creation of an "event" database, which functions as a GIS coverage. A customized Reach Indexing Tool (RIT) was developed as an extension to ESRI's ArcView desktop mapping software. The RIT was made available to the states through training courses and via the Web. Based on this experience, the states' official "designated uses" for tens of thousands of individual waterbodies are also being georeferenced to the NHD, as well as the locations of each state's fish consumption advisories and bans. The products of EPA's initiatives include detailed maps and GIS coverages, event tables that provide locational data linked to the NHD, and relational database files containing water quality information. The ultimate goal is to create data systems at the state level that can be easily compiled into uniform national data systems. Example products, including Web-based materials available to the public, are provided in this paper.

- **Implementing NHD Spatial Data in the U.S. Forest Service NRIS Water Application** [slides] [video]

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The U.S. Forest Service Natural Resource Information System (NRIS) Water application is designed to implement corporate data standards and promote integrated management of aquatic resource information, including physical and biotic data about stream and lake systems, water rights, and watershed improvement projects. The application consists of an Oracle database at its core, with supporting forms, reports, and add on tools which support user defined requirements. One of the primary requirements for the application was to represent survey units, watershed improvement sites, and water right structures in the GIS environment to facilitate spatial display and analysis. All of the data supported within the NRIS Water application is associated with real world physical features (e.g. segments of streams, lakes, roads, and points) that can be represented in GIS. The NRIS Water application refers to these as water map objects. Key to the design of the application is the use of water map objects to relate different types of data collected on one feature, or time series data collected on the same feature. To support this concept, a business rule was developed that requires all data entered into the database to be associated with a water map object, represented as a feature in a GIS. The first implementation of NRIS Water utilized GIS Core Data Standards internal to the Forest Service. Recent agency direction is to change the GIS Core Data Standards for linear hydrography and waterbodies to support the NHD data model. This decision was made primarily to support a National standard and to allow the agency to easily share data with a broad base of Federal and State agencies, and other publics. The use of spatial data in the NRIS Water application and the incorporation of the NHD data model will be presented. Issues, challenges, and solutions in incorporating the NHD spatial data model will be discussed.

- **High Resolution NHD Partnerships and Lessons Learned** [no slides] [video]

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The backbone of the NHD is now in place. It is starting to become what we envisioned it to be. Users are looking to it with a wide array of applications. It needs additional partners for the next stage of development for it to become more robust and comprehensive. Examples of existing partnerships and a wish list of what partners can do to support the continued development will be discussed.

- **NHD Flow Volume and Velocity Estimation** [slides] [video]

Greg Schwarz
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In order to model the transport and fate of contaminants in streams using the National Hydrography Dataset (NHD), it is necessary to have flow and velocity estimates for each NHD reach segment. To meet this requirement, a project has been initiated to develop estimates of mean annual flow and velocity, mean monthly flow, and corresponding high and low estimates for each item. The project will employ a hybrid deterministic/statistical approach that meets these qualifications. It is expected that NHD flow and velocity estimates will be closely integrated with water quality models. To facilitate this integration, it is imperative that the water quality models and the method for estimating flow and velocity share a consistent framework. The digital elevation model used to define basins for individual NHD reach segments should provide such a framework. This presentation will discuss the approach, status and plans for estimating NHD flow volume and velocity.

- **NHD Stream Order Possibilities** [slides] [video]

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The National Hydrography Dataset (NHD) combines the USGS Digital Line Graph mapping standards and the EPA Reach File capabilities into a single, more powerful system. Like the previous versions of the EPA Reach Files, the NHD contains three characteristics that are of great importance to analysts and modelers: (1) Each feature has a unique numerical identifier that permits cross-linking many different types of geo-referenced data; (2) the features contain a digital map representation which is very helpful for displaying and georeferencing of data; and, (3) reach-to-reach connectivity information is included that permits routing through the system both upstream and downstream. The NHD routing table design is more flexible than the previous Reach File routing tables, for instance, it permits much more flexible update capabilities (e.g., 1:100k to 1:24k) and junctions with more than two reaches at a confluence.

The routing/networking capabilities of the Reach Files, including the NHD, permit the development and application of a variety of analytical tools, including calculation of stream orders and water quantity and quality models. In addition, opportunities exist to define subsets of the reach network that can provide varying degrees of stream density. This ability to define different stream densities can play a critical role in future applications by being able to develop uniform coverages based on hydrologic factors; this general topic is referred to as "hydrologic equity".

This presentation will demonstrate the ability to use the NHD flow table and routing "engines" to calculate stream orders. Other examples will highlight methods for defining stream densities based on factors such as total river length, drainage area, and streamflow.

- **The Reach Address Database (RAD) - An Application-Ready NHD Implementation** [slides] [video]

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The U.S. Environmental Protection Agency (EPA) has constructed the Reach Address Database (RAD); a national seamless NHD database using ESRI SDE in an Oracle database. The RAD is designed to support multiple applications as well as allow for direct access by EPA users. We'll discuss the issues involved in putting the NHD "cans" together, loading the NHD into SDE, one design for an SDE implementation of the NHD (and why), and some common user needs for NHD data and how they influence the RAD's design. Included in this discussion will be event rendering using the NHD reaches and web access to the RAD.

Outline:

- Putting the NHD together (Append.AML issues, etc.)
- NHDinSDE (some RDBMS and SDE pointers)
- User Needs (Enviromapper for the EPA Office of Water, event storage/maintenance/etc., generic NHD/event user)
- Database Design Issues to Support Users (SDE tips, NHD tips, event tips)

- **Seamless Access and Delivery for the USGS's National Elevation Dataset** [slides] [video]

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The U.S. Geological Survey (USGS) and the Environmental Systems Research Institute (ESRI) have entered into a Cooperative Research and Development Agreement (CRADA) to prototype spatial data modeling, access, and distribution systems for large-scale databases. The National Elevation Dataset, at arc-second resolution, was loaded into an Oracle database for access by ESRI's Spatial Database Engine. Because the data were assembled from many sources and production methods, complete metadata require a spatial reference layer to track their lineage. A "metadata engine" clips out the necessary metadata "on-the-fly" for delivery with the requested elevation and/or land cover data. The resulting product can be staged for FTP access, or directed to offline media (e.g. CDR) that is then shipped to the customer. The system was designed to be in full compliance with USGS standards for metadata (FGDC) and for data transfer (SDTS). An OGIS connector provides for optional OGIS compliant connections. The seamless server will be used to provide imagery and thematic data for several GIS applications, including a rapid response demonstration project (e.g. Red River) and a web application for providing time-relevant environmental data (e.g. Sioux River Project Empact). It is hoped that this prototype will be the first in a series of USGS geospatial data servers that provide seamless access to Landsat imagery, Shuttle Radar Topography Mission (SRTM) data, and other applications that require browse and delivery of large images over the Internet.

Tuesday Lunch, December 12, 2000

- **Web-based NHD Update Concepts** [no slides] [no video]

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In order to maintain the accuracy and completeness of the National Hydrography Dataset at a 1:24,000 scale, it is critical that the data is readily available to willing and qualified individuals at their local desktops. Using ArcIMS technology, it is possible to create an Internet accessible application that will enable registered individuals to identify and correct errors in existing data, as well as make updates in a timely fashion online. Texas Natural Resources Information System will demonstrate how NHD data, through an application on the Texas Geography Network can be improved and updated by regional experts at remote locations.

- **The GIS Weasel - An Interface for the Development of Spatial Parameters for Physical Process Modeling** [slides] [no video]

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The GIS Weasel is a Graphical User Interface (GUI) driven tool that has been developed as an aid to modelers in the delineation, characterization, and parameterization of Modeling Response Units (MRUs) for use in distributed or lumped parameter physical process models. MRUs are usually defined as land surfaces that sub-divide an Area Of Interest (AOI), such as a watershed, to reflect a model's treatment of spatially distributed characteristics. MRUs can be homogeneous or heterogeneous with respect to some or all of these characteristics. The interface does not require user expertise in geographic information systems (GIS). The user does need knowledge of how the model will use the output from the GIS Weasel. The GIS Weasel uses Workstation ArcInfo 8.0.2 and the Arc Macro Language (AML), as well as scripts, and C subroutines. The GIS Weasel will run anywhere that Workstation ArcInfo runs (i.e. numerous flavors of Unix and Windows NT).

The GIS Weasel requires as input an ArcInfo grid of a Digital Elevation Model (DEM) that describes the topography of the AOI. The user may select the AOI from a set of watersheds that can be automatically delineated from the DEM based on ridges, define their own drainage area based on an interactively specified watershed outlet point, or use a previously created GRID or coverage. After the AOI is determined, a drainage network is extracted from the DEM. The user supplies a value for the minimum drainage area needed to support a channel. This value controls the density and configuration of the drainage network to be derived. Summary statistics and iterative trials allow the user to experiment before choosing the final value. Once the AOI and drainage network are established, MRUs can be delineated according to one or a combination of several methodologies including logical queries of topographic (elevation, slope, aspect, etc) or non-topographic (e.g. vegetation speciation, vegetation density, soils, etc) data, overlay analyses, and flow-based associations. An MRU can be composed of single, contiguous polygon or a grouping of non-contiguous polygons. Menu interfaces for examining and modifying the MRU map and its attributes are provided. The GIS Weasel provides version control and documentation to track modifications of MRU maps. Data derived from the original elevation grid (e.g.; slope, aspect) or other grids of attribute data (e.g.; vegetation, soils) can be examined on the basis of one or more MRUs, by grid cells (point-and-click), or attribute (logical query and reclassifications). The statistical distribution of an attribute within single MRUs or groups of MRUs can be shown. MRUs can be created, grouped, divided, or eliminated. Once MRUs are defined, user-selected model parameters can be generated using MRU attributes and their statistical measures. Output can be created in numerous formats, including an easy to read and reformat columnar, space delimited ASCII file.

For more information on the GIS Weasel, see http://wwwbrr.cr.usgs.gov/weasel.

Tuesday Afternoon, December 12, 2000

- **ArcGIS Geodatabase Models** [slides] [video]

Steve Grise
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ESRI is working with its customers to develop standard data model templates for twelve major business areas. This presentation discusses the application of object component and case tool technologies to produce these standard ArcGIS geodatabases.

- **Integrating the National Hydro Datasets** [slides] [video]

Dr. David Maidment
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This presentation describes the use of outlet points as an approach for integrating raster and vector water resources data in a way that doesn't require modifying the source data. The technique is demonstrated with an example from the Washita basin in Oklahoma using raster data from the National Elevation Dataset (NED) and vector data from the National Hydrography Dataset (NHD).

Wednesday Morning, December 13, 2000

- **The ArcGIS Hydro Data Model** [slides] [video]

Dr. David Maidment

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In September 1999, the Center for Research in Water Resources (CRWR) of the University of Texas at Austin and the Environmental Systems Research Institute (ESRI) formed a *Consortium for GIS in Water Resources* and invited industry, government and academic partners to join in the effort. The consortium is headed by Dr. David Maidment, Director of CRWR, and supported by software development staff at ESRI. The Consortium's goal is the design and implementation of a GeoDatabase model for surface water hydrology and hydrography using the new object modeling technology in ArcInfo version 8, and later in ArcView. A GeoDatabase model is a framework for capturing key geographic and descriptive information about a class of landscape features, and for attaching behaviors to the features. The GeoDatabase is accessed using ArcInfo version 8 software, in which objects interact through interfaces designed according to a common standard. This presentation conveys the current status and plans for the ArcGIS Hydro data model, and describes its various data structures.

- **NHD and National Water Information System (NWIS) Web Application** [slides] [video]

Tim Whiteaker
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This presentation describes an ArcMap application which dynamically retrieves time series data from the USGS National Water Information System (NWIS) through the Internet, and creates MS Access tables of the data using ArcGIS functionality. The application utilizes VBA code to read station ID's from a set of stream gages and retrieves the data based on a period of record that the user inputs. This presentation will provide a brief explanation of the code behind the application, and will list some of the possible benefits of linking time series to GIS through the Internet.

- **Map-making with the NHD** [slides] [video]

Bill Wheaton
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Making great looking maps with the NHD is surprisingly easy, but there are some tips and techniques that you should be aware of. This session will show you how to make the most of the NHD for cartographic applications and will illustrate some of the fine points of the data model that will help you exploit the true power of the NHD. We'll cover topics such as how to use each of the NHD feature classes in maps, how and where to apply feature labels (names) on your maps, how to handle issues related to artificial paths and connectors, and how to handle overlapping features, and drawing order. The session will illustrate these concepts and techniques using ArcView. However, they will also be applicable for Arcplot and Arcmap, as well.

- **Introducing the NHD ArcView Tool Kit** [slides] [video]

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The NHD ArcView Toolkit is a collection of ArcView extensions provided to assist in the understanding and use of NHD data. The Toolkit components are designed to be standalone tools or to be easily incorporated into user-developed, ArcView-based NHD applications. Currently, the Toolkit contains NHD Arc2Shape, which converts NHDinARC workspaces (coverage format) into NHDinSHP workspaces (shapefile format), and NHD Load/Unload Workspace, which loads, symbolizes and displays the themes and tables in one or more NHD workspaces, and NHD Navigate, which supports the upstream and downstream navigation of the drainage network using the NHD flow table.

- **NHD Names Update Tool** [no slides] [video]

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The National Hydrography Dataset (NHD) is destined to be maintained by stakeholders. Federal, state or local agencies or private sector organizations may chose to make updates or perform QA/QC on the updates of others. Since the NHD is designed to be a framework for cooperative data sharing, it is important that all updates yield a consistent dataset format and content. To this end, a robust set of update tools are needed. Update tools should be designed to (1) maintain the NHD data model during an update process, (2) support the gathering and formatting of metadata about update activity, (3) assist users in performing updates in an efficient and cost-effective manner, (4) insure, where possible, a consistent level of data quality, and, (5) enable the updater to easily submit the updates for inclusion in central NHD data holdings. This paper describes the on-going efforts of the USGS to develop NHD updating tools for NHD users. Specifically, the NHD update tool for names is described and demonstrated.

Wednesday Lunch, December 13, 2000

- **Basin Characteristics Panel Discussion** [no slides] [no video]

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Many hydrologic applications use characteristics of drainage basins above measurement points. One example is the USGS National Flood Frequency Program, which uses basin characteristics to estimate flood magnitude and frequency at ungaged sites. In the past, these basin characteristics most often have been derived by hand from topographic maps. Recently many basin characteristics have been calculated using GIS, but a lack of standard definitions and algorithms hampers widespread implementation by GIS vendors. The purpose of this panel discussion is to identify the most important basin characteristics and to begin to develop a set of standard definitions and algorithms by which these basin characteristics may be calculated.

Wednesday Afternoon, December 13, 2000

- **Implementing the 1:24,000 Scale NHD Model in Georgia** [slides] [video]

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The USGS is currently implementing procedures to produce the NHDinARC data model using 1:24,000-scale data. Information Technology Outreach Services (ITOS) at the University of Georgia is developing a parallel application, incorporating both ArcInfo and ArcView based software, to implement the 1:24,000-scale NHD model in the State of Georgia. An overview of the ITOS application will be presented.

- **Minnesota Hydrography Activities** [slides] [video]

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As with other states, managing, monitoring and assessing the vast surface water resources in Minnesota is a responsibility which is shared among various Federal, state, regional and local organizations. In an attempt to coordinate data issues resulting from these activities, the Minnesota Governor's Council on Geographic Information has formed a Hydrography Committee. The goal of the Committee is to foster the development, integration and sharing of hydrography data statewide. The efforts of the Committee to define a conceptual hydrographic framework for Minnesota and to coordinate higher resolution data development activities will be discussed.

One of the organizations with considerable responsibilities for monitoring and assessing the state's water resources is the Minnesota Pollution Control Agency. In trying to fulfill these responsibilities, the MPCA has been working to establish the National Hydrography Dataset (NHD) as the common reference from which to organize, track, integrate and report on the agency's surface water data collection, monitoring and assessment activities. The MPCA's efforts to integrate these data using the EPA's Reach Indexing Tool as well as efforts to develop 1:24,000 NHD data will also be discussed.

- **Use of the National Hydrography Dataset in BASINS 3.0** [slides] [video]

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Better Assessment Science Integrating point and Nonpoint Sources (BASINS) is a decision support system for watershed and water quality assessment and modeling. The system uses a highly customized ArcView GIS-based user interface to access the BASINS watershed models and databases through several data management utilities, assessment tools, and GIS-based model input preprocessors. Based on user needs and requirements; BASINS 3.0 will be released with more data, tools and models, in a reengineered system architecture. The defining feature of this new architecture is that all customized components of BASINS are distributed as extensions. This architecture is more open, flexible, scalable, and easily extensible.

One of the new data sets in BASINS is the National Hydrography Dataset (NHD). NHD is expected to be used extensively in BASINS for watershed modeling. Because of this, several BASINS components such as the manual and automatic watershed delineation tools were modified to handle NHD. In addition to delineating watershed boundaries, these tools are used to recreate the main stream network associated with the delineated watersheds and to determine watershed and stream attributes such as stream elevations, channel depths, channel widths, watershed area, watershed slope and watershed length. An NHD download tool has been developed to allow users to automatically download NHD coverages for selected 8-digit cataloguing units. These coverages are automatically converted to shape files, projected, and loaded into the current BASINS project. The development of the NHD download tool is an initial step towards integrating distributed databases for BASINS from different data sources available over the internet.

- **A Prototype for a USGS National Rivers Information Center** [slides] [video]

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The USGS has developed a Web application (http://ma.water.usgs.gov/streamstats) that provides streamflow statistics, such as the 100-year flood and the August median flow, for user-selected locations on streams in Massachusetts. Federal, State, and local agencies need streamflow statistics for such activities as (1) developing environmentally sound river basin management plans, (2) siting and permitting of new water withdrawals, inter-basin transfers, and discharges of pollutants, (3) determining the streamflow needs of aquatic plants and animals, and (4) land-use planning and regulation. Municipalities and other groups also need streamflow statistics for the design and management of water supplies, waste discharges, and power generation.

At the Web site, users are shown a map of Massachusetts with town boundaries and locations of USGS data-collection sites. They can zoom in to areas of interest and add more information to the map, such as roads, streams, and images of USGS topographic maps. Users can select the location of a data-collection site to get streamflow statistics for the site from a database or they can select any site on a stream to automatically get estimated streamflow statistics and prediction intervals that indicate the accuracy of the estimates for the site they selected.

The automated process for estimating streamflow statistics involves defining the drainage-basin boundary for the selected site, measuring other physical characteristics of the basin, and inserting the measured characteristics into equations that produce the estimates. Delineation of the drainage-basin boundary relies on a combination of a centerlined stream network, a State-wide subbasin boundary data layer and a digital elevation grid, all at 1:24,000 scale. The elevation grid is used to define the boundary from a selected point on a centerlined stream to the points at which the new boundary intersects any existing boundaries.

This Web application, which currently works only for Massachusetts, is seen by the USGS as a prototype for an on-line National Rivers Information Center that is currently being developed. The Center will initially provide only streamflow statistics, but water quality, water use, and other water-related information will likely be added in the future. The national application will rely on national datasets, such as the National Hydrography Dataset, and the National Elevation Dataset for determining the basin characteristics for user selected sites.

- **Massachusetts GIS-Watershed Tools** [slides] [video]

Peter Steeves
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A set of ArcView-based menu choices and tools has been developed for watershed analysis in Massachusetts by MassGIS, in cooperation with U.S. Geological Survey. These watershed tools include stream-network navigation functions, point event search functions, and watershed delineation functions. An underlying database was designed for rapid response to queries including determining all reaches upstream from a selected point and accumulating upstream sub-basin pour-points for use in delineating a basin boundary from any point on a stream network.

The Massachusetts watershed tools function through the use of three 1:24,000 scale data layers: surface-water hydrography, land-surface elevation, and basin boundaries. Each of these data layers has been modified to work with the tools. The integrated data layer environment allows for accurate basin delineation and easy cross-attribution of data layers (for example a newly delineated watershed obtains the reach code and mile-marker measurement from the point of delineation on the stream network).

Hydrologic applications have been developed using watershed tools in Massachusetts, including stream-flow, water-quality and habitat studies.

Efforts are underway to integrate the Massachusetts watershed tools into the NHD ArcView Toolkit using national data layers.

- **STORET Water Quality Database and the NHD** [slides] [video]

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The U.S. Environmental Protection Agency (EPA) maintains two data management systems containing water quality information for the nation's waters: the Storet Legacy Data Center, and modernized STORET. STORET is short for STOrage and RETrieval. The Storet Legacy Data Center, known as the LDC, contains historical water quality data dating back to the early part of the 20th century and collected up to the end of 1998. Modernized STORET contains data collected beginning in 1999, along with older data that has been properly documented and migrated from the LDC.

Both systems contain raw biological, chemical, and physical data on surface and ground water collected by federal, state and local agencies, Indian Tribes, volunteer groups, academics, and others. All 50 States, territories, and jurisdictions of the U.S., along with portions of Canada and Mexico, are represented in these systems. Each sampling result is accompanied by information on where the sample was taken, when the sample was gathered, the medium sampled (e.g., water, sediment, fish tissue), and the name of the organization that sponsored the monitoring. In addition, information on why the data were gathered; sampling and analytical methods used; the laboratory used to analyze the samples; the quality control checks used when sampling, handling the samples, and analyzing the data; and the personnel responsible for the data is also available.

This presentation will provide a general overview of the LDC/Modernized Storet and will address efforts to integrate the systems with the National Hydrography Dataset (NHD) for mapping and analytical purposes.

- **Developing a National Data Base of Watersheds and Watershed Characteristics for Community Water Systems that Withdraw from Surface Water** [slides] [video]

Michael E. Wieczorek and Joel D. Blomquist
U.S. Geological Survey
Baltimore, Maryland
mewieczo@usgs.gov

The U.S. Geological Survey (USGS) is participating in a multi-agency program to delineate watershed boundaries and characterize the watersheds contributing to community water systems that withdraw from surface water throughout the Nation. No National databases that describe source areas for U.S. water supplies are currently available. Therefore, national efforts to effectively identify high-risk water supplies and to focus drinking-water monitoring programs have lacked critical information. The watershed-characterization project was developed based on an analysis of information requirements for the USGS National Water-Quality Assessment Program and the U.S. Environmental Protection Agency's Office of Pesticide Programs. Thus, one of the first uses of the data set will be an evaluation of the pesticide-use rates upstream from all drinking-water supply intakes in the Nation.

The Oak Ridge National Laboratory has been contracted to delineate watersheds and characterize pesticide-use rates using techniques tested by the USGS. The methods are based on the National Hydrography Dataset (NHD), where each water-supply intake is associated with an individual NHD stream reach. Watershed delineation takes advantage of the NHD topologic structure. This approach has been tested for 237 water-supply intakes using the BETA version of NHD. An Arc/Info regions model was created from NHD's contiguous United States basin coverage and used to aid in the delineation of some of the larger watersheds because watersheds range in size from several hectares to millions of square kilometers.

- **Criticality of Point Features in NHD-Based Hydrologic Modeling** [slides] [video]

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Inclusion of point features (lakes, dams, reservoirs, and monitoring and sampling stations) and their positional accuracy will have significant impact on successful utilization of the National Hydrography

Data (NHD) in various hydrologic modeling exercises. The location of point features are important in the context for two reasons: (1) they serve as critical junctions on a hydrologic system where flow and velocity characteristics change, and (2) they may impact contaminant concentrations at a downstream location through retardation and/or storage of runoff water and stream flow. Initial developments of appropriate data sets and tools for data manipulation are necessary and critical preceding steps that will compliment the future modeling efforts. This project attempts to reference and associate Community Water System (CWS) intake locations and the national Inventory of Dams (NID) to the NHD. Currently, 2,243 CWS locations have been verified to the accuracy of 6-seconds with respect to the RF1 data set. Location verification work for another 7,000-10,000 CWS intake points will be completed soon and are expected to be available during the course of this project. Approximately 1,800 impoundments are currently identified in RF1 out of the approximately 75,000 dams listed in the US Army Corp of Engineer's National Inventory of Dams (NID). A mostly automated assignment tool is being developed, which will utilize an algorithm to identify and assign individual CWS locations to appropriate NHD reaches. This algorithm will be based on a combination of proximity analysis (distance snapping) and attribute (name) matching using the Geographic Name Information System (GNIS).

- **ESRI's Water Resources Extension Tools** [slides] [video]

Dean Djokic
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This presentation will discuss the planned transition to ArcInfo and ArcView 8.1 technology of hydrologic and hydraulic modeling support tools developed at ESRI and used in water resources community. Special emphasis will be placed on the transition of watershed delineation, HEC-GeoHMS, and HEC-GeoRAS tools, and integration with the ArcHydro data model.

Thursday, December 14, 2000

- **Introduction to the NHD Training **** [no slides] [no video]

The National Hydrography Dataset is a combination of the USGS 1:100,000 scale hydrography data and the EPA Reach data. The dataset is structured to allow flow modeling of the hydrography data and to easily attach agency specific attribute data to the reaches. The data is in the new USGS enhanced model, that imports into ArcView.

This class will be a hands on introduction to the National Hydrography Dataset. The topics covered will be an indepth overview of the NHD model, how to download the data from the website, the steps in loading the data into ArcView using the NHD toolkit, and example exercises in linking the NHD with external datasets.

- **Reach Indexing Tool (RIT) Training** [no slides] [no video]

The Reach Indexing Tool for NHD (NHD-RIT) is an ArcView extension that allows users to georeference surface water data (like fish consumption advisories or 305(b) assessments) to the National Hydrography Dataset. This process of identifying and assigning surface water ID's or attributes to portions of NHD is referred to as Reach Indexing. The NHD-RIT training session includes an overview of how NHD event tables (the product created by the NHD-RIT) can be used to display surface water attributes (like assessment or advisory information) stored in a database. Attendees will learn how to use the Reach Indexing Tool to create and edit NHD event tables for linear, point and areal features. The individual tutorials introduce new users to all of the functionality included in the NHD-RIT, culminating in a "real world" exercise where the students must use what they have learned to reach index. Attendees will also learn how to link georeferenced waters to a surface water attribute database using ArcView's SQL Connect feature and Open Database Connectivity (ODBC).

- **Moving to High Resolution NHD Seminar** [no slides] [no video]

The NHD, while originally based on 1:100,000-scale linework, is designed to incorporate high-resolution data. USGS is developing ArcInfo and ArcView based tools that will allow partners to create NHD data using other sources of linework. This workshop will provide an in-depth description of the various steps in the process. Major steps include: pre-conflation, which creates a watershed based, connected network with arcs directed downstream and centerlines; conflation, which transfers the appropriate information from the 1:100,000-scale NHD; and post-conflation which validates the flow direction attributes and creates all the necessary tables that are part of the NHD. The tools will be demonstrated and examples of interactive processes will be shown. Sorry, no hands on data creation so don't bring your data and hope to leave with a complete high-resolution NHD dataset.

- **NED-H Stage 2 Seminar** [no slides] [no video]

The National Elevation Dataset - Hydrologic (NED-H) derivative dataset serves to integrate three of the USGS' datasets - the National Elevation Dataset, the National Hydrography Dataset and the Watershed Boundaries Dataset. The NED-H is being developed in a three stage process. Stage 1 derives hydrologic derivatives via a semi-automatic ARC/INFO process. Stage 2 utilizes ArcView tools to create preliminary watersheds and sub-watersheds and to identify and annotate discrepancies between NED derived derivatives and the NHD or other datasets used for verification. Stage 3 will use output data and information from Stage 2 to develop a hydrologically conditioned NED dataset that will subsequently be used to derive the final NED-H hydrologic derivative dataset.

This seminar is concerned with the Stage 2 aspects of the NED-H project. In Stage 2, NED-H participants lend their local knowledge to the quality checking process, reviewing the NED-H derived streamlines and drainage basins as well as locating watershed and subwatershed outlet points. The tools have been developed, and continue to be refined through a CRADA with ESRI, to facilitate this work. This seminar will summarize the status of the Stage 2 effort, present the ARCVIEW tools currently being used by Stage 2 collaborators across the country and discuss lessons learned by the on-going participants.

Unless otherwise noted below, all sessions were held at the Commons Building on the JJ Pickle Research Campus (University of Texas).

> ** - session was held at the USGS Office, 8027 Exchange Drive, in Austin

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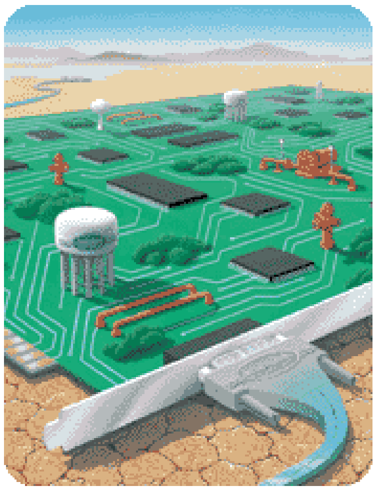

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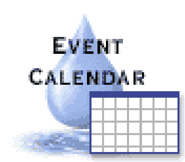

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SAAESD Southern Association of Agricultural Experiment Station Directors

Southern Region Research Project S-273

Development and Application of Comprehensive Agricultural Ecosystems Models

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- General Project Information
  - Current Officers and Advisor
  - Final Draft of the Regional Project (S-273)
  - Project Objectives
  - E-Mail addresses and WWW home pages of Project Participants
    - Click  HERE to send a message to the group.
- Annual Reports
  - 2001
  - 2000
  - 1999
  - 1998 - Appendix of Project History by John "Ike" Sewell
  - 1997
- Meeting Minutes
  - 2001
  - 2000
  - 1999
  - 1998
  - 1997

Annual Meeting Information

- 2001 Annual Meeting - Washington, DC, October, 2001 (tentative)

- 2000 Annual Meeting - Texas, October 16-17, 2000
  - Minutes
  - Agenda
  - Local Arrangements - Hotel and Travel Information Information
  - NC - Slides for the Meeting - Details to go with the verbal report
  - Slides from our visit to the Animal Facility and the Ocean Drilling Program (Click Save As to get a copy - from the directory-these should be suitable for including in a powerpoint presentation)
- 1999 Annual Meeting - Knoxville, Tennessee, October 18-19, 1999
  - Minutes
  - Agenda
  - Directions and other Information
- 1998 Annual Meeting - Stillwater, Oklahoma, October 19-21, 1998
  - Minutes from the 1998 Meeting
  - Some pictures from the Meeting
  - Agenda
  - Directions
- 1997 Annual Meeting - Ames, Iowa October 20-22, 1997
  - Minutes from the 1997 Meeting
  - Announcement and other Information

- Project History
- Project Accomplishments and Impact Statements
- Online Bulletins and Other Documents from the Group
- Ongoing Cooperative Projects to
  - Evaluate Use and Application of Water Quality Models
    - Style Guide and Information on the Format of the Final Web Publication
- Other Announcements of Interest to the Group - Job Openings, ...
  - TMDL Conference on Science Issues (USGS) March 4-7, 2001 in St. Louis (posted 12/15/00)

    - Technical Support Job with USDA-ARS in Baton Rouge, LA (posted 1/25/99)
    -
- Other Sites of Interest
    - Southern Association of Agricultural Experiment Station Directors
    - CSREES - Cooperative States Research, Extension, and Education Service
    - EPA TMDL Program
    -
- Previous Project Information (S249)
- North Carolina's Involvement
    - Participants from North Carolina
    - North Carolina Annual Report (1995)
    - North Carolina Annual Report (1996)
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    - North Carolina Annual Report (1998)
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    - North Carolina Annual Report (2000)
    - North Carolina Annual Report (2001)
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Contact us for more information.

- NEW!

Agricultural Non-point Source Water Quality Models: Their Use and Application

Sponsored by ASCE, Water Resources Engineering Division, Agricultural Water Quality Committee and Southern Region Research Project S-273

Hydrologic/Water Quality Model Use and Application Evaluation Project

- Initial Project Layout
- Original Evaluation Criteria from 1996 Greensboro, NC meeting
- Reviews and other information on Selected Models by the NCSU Water Quality Modeling Class
- Minutes from 1997 Meeting in Minneapolis, MN
- Revised Criteria from the Minnesota Meeting
- Minutes from 1998 Meeting in Orlando, FL (pdf version)
- Peer Review forms for the Papers (Information, Word, Wordperfect, html)
- Style Guide and other information for the final web publication

PDF versions of the papers presented at the Orlando, FL 1998 ASAE Meeting

The following papers were presented as part of the Model Evaluation Project at the 1998 International ASAE Meeting in Orlando, Florida - July 13-15, 1998. If you would like more information, contact the authors directly.

- Agricultural Non-Point Source Water Quality Models: Their Use and Application, Thomas (pdf)
- Evaluation Criteria for Water Quality Models, Parsons (html) (pdf)
- Evaluation of the AnnAGNPS Water Quality Model, Bosch (pdf)
- Evaluation of DRAINMOD, Parsons (pdf)
- Evaluation of the RUSLE Soil Erosion Model, Yoder, etal. (pdf)
- ANSWERS-2000, (pdf)

- Evaluation of the Water Quality Model EUTROMOD, Hession et al. (pdf)
- Opus: Model Description and Evaluation, Heatwole (pdf)
- GLEAMS Model (pdf)
- Evaluation of the WAVE model, Munoz (pdf)
- Evaluation of the TOPMODEL, Ma Pilar (pdf)
- Evaluation of the Root Zone Water Quality Model (RZWQM), Malone (pdf1 pdf2 pdf3 - text and tables)
- Evaluation of QUAL2E (pdf)
- Evaluation of the MIKE SHE Modeling System (pdf)
-
- Use and Application of the Soil and Water Assessment Model (SWAT) (pdf)
- Evaluation of SIMPLE (pdf)
- Addition Papers - Applications
  - ARCVIEW-GLEAMS Integration for Pesticide Source Loading Estimation - Manguerra (pdf)
  - Comparing the Inputs and Outputs of the GLEAMS, RUSLE, EPIC and WEPP Models - Reyes (pdf)
  - Application of the SCS Curve Number Method to Mildly-Sloped Watersheds - Walker (pdf)

Status Matrix of the Project

Peer Reviewer Infomation

Last Update 09/19/00

Hydrologic Engineering Center

Last Updated: 18 Apr 01

Software

- **Distribution Policy**
- **Computer Program Catalog**
  (in PDF format)
- **Vendor List**
  (in PDF format)
- **Year 2000 Compliance**
- **Software to Download**

To Home Page

HEC has been developing computer programs for hydrologic engineering and planning analysis procedures since its inception in 1964. Software has evolved from computerized procedures to complex modeling systems. The software runs on main-frame, PC-DOS compatible computers, UNIX workstations and Windows PC's. Executable PC programs are made available to non-Corps' offices through NTIS and a network of program vendors (SEE VENDOR LIST).

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BASINS
Better Assessment Science Integrating Point and Nonpoint Sources

BASINS 2.01 is the current release. This release includes additional functional capabilities as well as an updated and expanded set of national data layers. A BASINS User's Manual, the system files, documentation, and the data are available in the downloads section.

NEW! **BASINS 3** is now in beta release.

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Environmental Protection Agency's Office of Science and Technology

GIS Water Resources Consortium

The Center for Research in Water Resources (CRWR) of the University of Texas at Austin, and the Environmental Systems Research Institute, Inc. (ESRI) have established a Consortium for developing and implementing new Geographic Information System (GIS) capabilities in Water Resources. The initial focus of the consortium is on design of a new GeoDatabase Model for Rivers and Watersheds for ArcInfo version 8. The consortium is headed by Dr. David R. Maidment, Director of CRWR, and supported by software development staff at ESRI. Interested organizations and individuals are invited to join the consortium.

- National Hydrography Dataset (NHD) Applications Symposium December 11-14, 2000
- GIS Hydro 2000 CD
- GIS in Water Resources Conference, June 2000
- GIS in Water Resources Conference, February 23-25, 2000
- Membership in the Consortium
- Arc Hydrology Data Model files
- Data Model Discussion Server
- Opportunities for Research or Employment
- Technical Plan for GeoDatabase Model Development
- First Organizational Meeting of the Consortium
- Document Library
- Websites
- GIS in Water Resources Online Course
- GIS in Water Resources Community
- National Hydrography Dataset
- Contacts

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Bureau of Engineering Research
The University of Texas at Austin

GIS in Water Resources Consortium
ArcGIS Hydro Data Model

Chapter 3

Hydro Network

The heart of the ArcGIS Hydro Data Model is the Hydro Network. The Hydro Network is made up of the Hydro Edge and Hydro Junctions that represent the river system, and is augmented by Waterbodies and other special features.

- Hydro Network Components
- Linear Referencing
- Building a Hydro Network
- Tracing Flow through a Hydro Network
- Hydro Network UML Diagram

Click here to view the PDF version of Chapter 3.

Chapter 3 Data

The Hydro Edges are in a class called Edges representing the NHD reaches for the Lower West Fork of the Trinity River. All the point features are in Hydro Points under the classes Monitoring and stuff. The Edge Catchments are in Catchments and link by Grid-code to ObjectID of Hydro Edges.

The geodatabase (in zipped format) can be found in the folder ArcGIS\Chapter3\Chapter3data, along with the DLL file needed in order to run the ArcGIS Hydro Data Model in ArcCatalog or ArcMap. For instructions on how to use the DLL file and deploy the data model, go to the Instructions page.

I have included the DEM (lwf_dem) and the FlowDirection Grid (lwf_fdrgr) and it is in the on the CRWR ftp site at ftp://ftp.crwr.utexas.edu/pub/consortium/LWF.

Chapter 3 Display

The data from Chapter 3 can be viewed as a map document in ArcMap.

The map can be found in the folder ArcGIS\Chapter3Data and viewed in ArcMap.
